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Nationwide Urban Runoff Program, Tampa, Florida Phase 1 Final Report

Tampa Dept. of Public Works, FL

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TAMPA, FLORIDA 33602

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NATIONWIDE URBAN RUNOFF PROGRAM

PHASE I
FINAL REPORT

JANUARY, 1981

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16. Abstract (Limit: 200 words) This initial phase of the investigation was conducted to summarize the current status of water quality problems and pollution sources in the Study Area. The need for further study of the effects of urban stormwater on the receiving waters is identified. Locations where stormwater would be best studied, the type of measurement qo quantify stormwater runoff and assess its effects on the receiving waters were determined. Important issues to be included in additional phases of the study were outlined.

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PREFACE

This report presents the findings of the City of Tampa, Nationwide Urban Runoff Program Phase I Study. The goal of Phase I was to compile existing data and identify the relative magnitude and impact of non-point source pollution in three receiving bodies of water adjacent to the City of Tampa. The scope of the study included an inventory of all point sources in the area, estimation of the volume and concentration of non point source pollution, evaluation of receiving water conditions and an assessment of the impact of urban runoff on the biology of the area. This report is presented in two sections, first an overall assessment outlining findings of the entire study, followed by a compilation of detailed outputs from each task in the Phase I scope.

The project was funded by the U.S. Environmental Protection Agency and the City of Tampa. Funds were made available through the Florida Department of Environmental Regulation. Technical outputs were produced by the consulting firms of Metcalf and Eddy, Incorporated, Boston, Massachusetts and Priede-Sedgwick, Incorporated, Jacksonville, Florida. The project was managed by the City of Tampa Department of Public Works.

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Special thanks are extended for input to the project from the Technical Advisory Committee (TAC), Citizens Advisory Committee (CAC), City Management Committee (CMC) and EPA/NURP consultants. Technical review of the project output was conducted by EPA/Washington, EPA Region IV, FDER/Tallahassee, FDER/Tampa, EPA/NURP consultants, TAC, CMC, and Department of Public Works staff. A special acknowledgment is extended to City staff both in the Department of Public Works and other Departments for their efforts during Phase I of the NURP study.

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OVERALL ASSESSMENT

General

The purpose of this assessment is to summarize the work done in Phase I of the Nationwide Urban Runoff Program (NURP) in Tampa and to identify the direction to be taken in Phase II. This is done by first presenting an overview of water quality problems and pollution sources in the Study Area, (see Figure 1-1). The need for further study of the effects of urban stormwater on the receiving waters is identified. The remaining sections describe where stormwater would be best studied, the type of measurement program needed for Phase II and the analysis techniques proposed to quantify stormwater runoff and to assess its effects on the receiving waters. Finally, several important issues in Phase II are outlined. In this assessment there are frequent references to Phase I Task outputs previously submitted to the City where more detailed information has been provided.

Overview of Water Quality Problems in the Receiving Waters

Over the past 20 years there has been a wide variety of studies conducted in the Hillsborough Bay/Tampa Bay system and to a lesser extent in the Hillsborough River system. The literature describing these studies is summarized in the output for Task 1.3e by Priede-Sedgwick (P-S). The concerns that prompted much of the previous work included eutrophication nad odor problems, reduction in commercial fisheries and seagrasses, and fish kills. Causes for these problems have been identified by the individual investigators as urbanization, industrialization, dredging, and unusually high phosphorus concentrations due to naturally occurring phosphorus deposits and the phosphate industries located to the east of the Bay System.

Positive steps have been taken to reduce pollution loads in an effort to reverse the deterioration in water quality. In the early 1970's phosphorus coming from industrial plants was reduced and the City of Tampa upgraded its wastewater treatment plant at Hookers Point from primary to secondary treatment in 1978 and from secondary to advanced treatment in 1979. With these significant improvements in the quality of point source discharges it becomes important to focus attention on other sources of pollution such as urban runoff. The City of Tampa has begun this process by implementing a number of stormwater controls described in the output for Task 1.5 by the City of Tampa. However, there has been little effort to determine the need or effectiveness of these stormwater controls.

As part of Phase I of the NURP Project an assessment was made of the most recent water quality data to identify possible

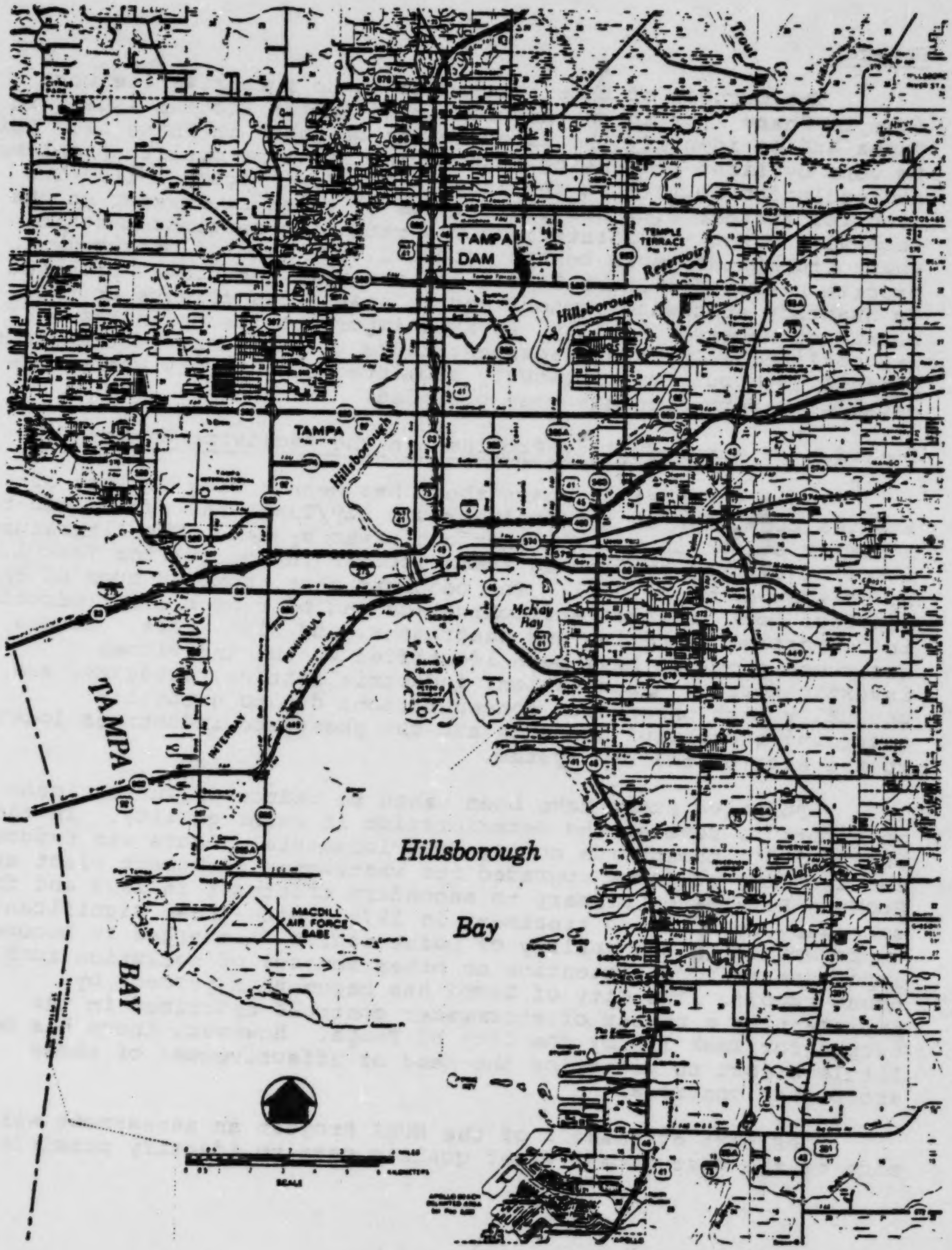
Trout
THONOTOSASSA
TAMPA DAM
TEMPLE TERRACE
Reservoir
Hillsborough
River
TAMPA
Hillsborough
McKay Bay
PENINSULA
INTERBAY
TAMPA
BAY
Hillsborough
Bay
MACDILL AIR FORCE BASE
Alafia
SCALE

FIG. 1-1 STUDY AREA

problems and to see if a cause and effect relation existed between urban stormwater runoff and changes in water quality. The results are based on data collected in the Hillsborough Bay in 1979 and in the Lower Hillsborough River and the Hillsborough Reservoir in the latter half of 1978, in 1979 and in the beginning of 1980.

This period was selected because: it provides the most recent data, is the only period when data for all three water bodies are available, is least affected by the Hookers Point Wastewater Treatment Plant, and is a year with above average rainfall. This period has limitations in that there were reported sanitary sewer overflows in the Lower Hillsborough River during a portion of 1979 which contributed, along with urban runoff and other sources, to water quality problems. The water quality assessment is presented in the output for Task 1.3d by Metcalf & Eddy (M&E) and is summarized here.

Hillsborough Bay. Intermittent violations of state standards for dissolved oxygen and coliform concentrations occur during wet weather. Dissolved oxygen is generally above 4 mg/l until the wet season when concentrations drop below 4 mg/l. The lowest concentrations occur near the bottom in the northern portion of the Bay including McKay Bay (see Figures 2-6 and 2-7 in the output for Task 1.3d). Total coliform concentrations are above 1,000 MPN/100 ml for several months during the year, particularly during wet weather. The highest concentrations occur during the wet season in the northern portion of Hillsborough Bay and McKay Bay (see Figures 2-11 and 2-12 in the output for Task 1.3d). There is an advantage in looking at water quality in McKay Bay because sanitary sewer overflows are least likely to interfere with its water quality. Therefore, changes in McKay Bay during wet weather can be more directly linked to stormwater runoff.

Nutrient concentrations including phosphorus and nitrogen are consistently high throughout the Bay during both dry and wet weather (see Figures 2-13 and 2-14 in the output for Task 1.3d). Concentrations are in excess of the amount needed to support algal growth, resulting in algal blooms. Phosphorus concentrations are higher than nitrogen concentrations, and nitrogen concentrations fluctuate widely, indicating greater sensitivity of nitrogen to changes in external inputs and algal activity.

Lower Hillsborough River. Violations of state standards for dissolved oxygen and coliform concentrations occur in this water body. The dissolved oxygen concentrations are affected by the freshwater flow in the River. At lower flows, salt water penetrates into the lower River and bottom material appears to exert a large oxygen demand. Under these conditions dissolved oxygen concentrations are consistently below 4.0 mg/l and at times equal to zero in the bottom waters (see Figures 3-7 and 3-8 in the output for Task 1.3d). Generally the lowest DO concentrations occur in the middle reaches of the River 2 to 6 miles below the Tampa Dam.

Fecal coliform concentrations in the Lower River periodically violate state standards with concentrations measured above 100,000 MPN/100 ml. The higher coliform concentrations occur after wet periods (see Figures 3-9 in the output for Task 1.3d). High coliform counts occur throughout most of the River with the exception of the upstream section for about one mile below the Tampa Dam.

Hillsborough Reservoir. Data in Hillsborough Reservoir indicate violations of state standards for dissolved oxygen concentrations, high nutrient concentrations and moderately high concentrations of lead and mercury. Dissolved oxygen concentrations below 4.0 mg/l occur throughout the year but predominate in the summer months in the bottom waters (see Figures 4-4 and 4-5 in the output for Task 1.3d). Surface dissolved oxygen is generally above 4.0 mg/l.

Nitrogen and phosphrous concentrations in the Reservoir are above the limits necessary to support algal blooms. Phosphorus concentrations are fairly constant throughout the year (approximately 0.5 mg/l as orthophosphate) while nitrogen concentrations are lowest (approximately 0.3 mg/l as inorganic nitrogen) during the high flow periods in the summer (see Figure 4-9 in the output for Task 1.3d).

Two heavy metals were measured in concentrations that could indicate potential problems for fresh water aquatic life. Lead concentrations average approximately 0.02 mg/l and mercury concentrations averaged approximately 0.0005 mg/l (see Table 4-2 in the output for Task 1.3d). Metal concentrations are generally highest after rainfalls during the dry season.

Summary. Hillsborough Bay, the Lower Hillsborough River, and Hillsborough Reservoir are all affected in various ways by wet weather flows and loads of which urban stormwater runoff is a part. These effects may be either adverse or beneficial. The adverse impacts result in water quality problems which may need to be addressed through remedial actions. These adverse impacts and the water quality issues they raise are summarized in Table 1-1.

The existing data base used to identify water quality problems are not collected specifically to define the role of urban stormwater runoff and is not adequate to establish a cause and effect relationship between urban runoff and water quality. The receiving water data consists primarily of single samples taken throughout the receiving water system once per month. It is not clear, for this data, to what extent urban runoff contributes to water quality problems when compared to other sources of pollution such as river flows and point sources. Existing data

TABLE 1-1. SUMMARY OF ADVERSE WET WEATHER EFFECTS IN EACH RECEIVING WATER BODY IN THE STUDY AREA

Receiving water body	Parameters showing adverse trends during wet weather	Actual and expected Water quality issues
Hillsborough Bay	Dissolved oxygen	-Violations in State Standards, Deterioration in Aquatic Life, Fish Kills
	Nutrients	-Eutrophication, Odor Problems, Aesthetic Deterioration
	Coliform Bacteria	-Violation of State Standards, Public Health Problems, Restriction in use
Lower Hillsborough River	Suspended Solids	-Build up of Bottom Depsoits, Deterioration in Benthic Life, Aesthetic Deterioration
	Coliform Bacteria	-Violation of State Standards, Public Health Problems, Restriction in use
Hillsborough Reservoir	Dissolved Oxygen	-Violations in State Standards, Deterioration in Aquatic Life
	Nutrients	-Eutrophiciation, Odor Problems, Aesthetic Deterioration, Increased Costs to Water Treatment
	Metals	-Deterioration in Aquatic Life, Protection of Drinking Water Supply

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needs to be supplemented by short term programs which are designed to specifically show conditions before, during and after storm events.

At the same time receiving water measurements are being taken, it is also necessary to quantify the pollution load entering the system. Although data is available to make preliminary estimates of pollution loads it has not been collected to coordinate with receiving water programs. Therefore, data describing receiving waters and pollution loads cannot be coupled to draw cause and effect relations for specific events. However, it is possible from the existing data to make preliminary estimates and compare typical pollution loadings from different sources. This is useful information to help judge the relative impact of urban stormwater when compared to other pollution sources.

Overview of Pollution Sources

An important step in any assessment of stormwater runoff is to identify other main sources of pollution and estimate the magnitude of each in relation to stormwater runoff. This was done in the output for Tasks 1.3b and c by P-S and the procedures and results are summarized in this section.

The principle source contributing pollution loads to the receiving waters, in addition to urban runoff, are point sources, both municipal and industrial, and river flows entering from outside the study area. The method used to quantify flows and pollution loads from each source is described as follows:

1. Urban stormwater runoff was quantified using regression equations developed on a preliminary basis by the USGS based on data collected between 1975 and 1980 in nine urban basinss in the Tampa-St. Petersburg area.
2. Point sources were quantified based on compliance monitoring data, when available, and state and federal discharge permit information.
3. River flows were quantified by using flow and water quality data from USGS and County gaging and sampling stations and adjusted to different locations, when needed, based on a ratio of drainage areas.

The above methods were used to estimate flows and pollution loads for two different time periods. The selection of a given time period is important because stormwater runoff occurs intermittently and other sources normally occur continuously so that changing the time period can change the relative importance of each source. A longer term period of one month was selected to cover several storms and reflect a cumulative impact of runoff with respect to other continuous sources. A second time period of several days was selected to cover a single storm and reflect the impact of short term loadings. Each of these two time periods were quantified during the wet season (July-October) and during the dry season (November - June). A typical month during each season was selected based on a review of 40 years of rainfall records. The individual storm selected to compare short term impacts consisted of approximately 2.0 inches of rain which would occur about once per year in one hour.

The loading distribution by source, developed in Task 1.3b and c by P-S, is summarized in Table 1-2 for the one month period, and in Table 1-3 for the single storm period. As expected the shorter time frame shows the largest impact from stormwater runoff. For the shorter duration period urban runoff can contribute as much as 65-70 percent of the BOD_5 and suspended solids in the Lower River during the dry season. A somewhat lesser impact is shown for the Hillsborough Reservoir and Bay. For the longer time period of one month, the same trends occur with urban runoff contributing as much as 40 percent of the BOD_5 and suspended solids in the lower River.

The loading distribution shown in Tables 1-2 and 1-3 indicate that urban runoff can contribute a significant portion of selected pollutants to the receiving waters.

In developing these preliminary estimates there were several important gaps in the existing data base that were identified. For example, for some sources, such as the Hookers Point Treatment Plant, detailed long term daily data was available while for other sources data was limited, not available, or out dated. For selected point sources, measurements and samples need to be collected for certain pollutants in order to improve the loading estimates. In the case of River inputs, changes in nitrogen concentrations reported by the HCEPC need to be resolved. In the case of stormwater runoff, additional data needs to be collected to increase the confidence in predicting the characteristics of controlled and uncontrolled urban runoff in the Tampa area.

Filling in the data gaps mentioned above is necessary to improve on the preliminary estimates of pollution loads to the receiving waters. It is also important to coordinate any measurements of pollution sources with measurements in the receiving waters so that cause and effect relationships can be studied for specific time periods.

Need to Study Urban Stormwater Runoff

The NURP Program has been initiated nationwide in 30 cities because stormwater runoff has been identified, largely through 208 Areawide Planning Studies, as a major contributor of pollution in

TABLE 1-2. ESTIMATED MONTHLY POLLUTANT LOADINGS TO EACH RECEIVING WATER BODY BY SOURCE[1]

Receiving water segment	Pollutant	Percent of total monthly pollution load by source: Urban runoff[2] Dry month Wet month	River flows[3] Dry month Wet month	Point sources[4] Dry month Wet month
Hillsborough Bay	Biochemical Oxygen Demand	10-5	65-80	25-15
	Suspended Solids	5-5	75-90	20-5
	Total Nitrogen	5-5	70-90	25-5
	Total Phosphorus	1-1	75-90	25-10
Lower Hillsborough River	Biochemical Oxygen Demand	35-25	65-75	0
	Suspended Solids	40-20	60-80	0
	Total Nitrogen	35-25	65-75	0
	Total Phosphorus	10-5	90-95	0
Hillsborough Reservoir	Biochemical Oxygen Demand	20-15	80-85	0
	Suspended Solids	15-15	85-85	0
	Total Nitrogen	15-15	85-85	0
	Total Phosphorus	5- 5	95-95	0

1. Results from outputs from Tasks 1.3b and c by Priede-Sedgwick.
2. Urban runoff represents pollution loads from the urban areas adjacent to the water bodies.
3. River flows represent pollution loads from the Hillsborough, Alafia and Palm Rivers.
4. Point sources represent those discharging directly to the water bodies.

TABLE 1-3. ESTIMATED SHORT TERM POLLUTANT LOADINGS TO EACH RECEIVING WATER BODY BY SOURCE(1)

		Percent of short term pollution load by source(1)		
		Urban runoff(2)	River flows(3)	Point sources(4)
Receiving water segment	Pollutant	Dry season Wet season	Dry season Wet season	Dry season Wet season
Hillsborough Bay	Biochemical Oxygen Demand	25-15	45-70	30-15
	Suspended Solids	35-20	50-70	15-10
	Total Nitrogen	15-10	50-75	35-15
	Total Phosphorus	5-1	65-80	30-20
Lower Hillsborough River	Biochemical Oxygen Demand	70-40	30-60	0
	Suspended Solids	65-20	35-80	0
	Total Nitrogen	55-25	45-75	0
	Total Phosphorus	25-10	75-90	0
Hillsborough Reservoir	Biochemical Oxygen Demand	55-30	45-70	0
	Suspended Solids	50-30	50-70	0
	Total Nitrogen	25-15	75-85	0
	Total Phosphorus	15-5	85-95	0

1. Results from outputs for Tasks 1.3b and c by Priede-Sedgwick.
2. Urban runoff represents loads from the urban area adjacent to the water bodies.
3. River flows represents loads from the Hillsborough River, Alafia River and Palm River.
4. Point sources represent those discharging directly to the water bodies.

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urban areas. Congress in the 1977 Clean Water Act Ammendments, recognized a national need and allocated resources to develop a better understanding of the problems and possible solutions associated with urban stormwater runoff. Specifically in the Tampa area, there is a need to develop a management plan to deal with both the quantity and quality aspects of stormwater runoff. Such a plan should address existing water quality problems, support the cities' efforts to deal with flooding problems in an environmentally sound manner, and satisfy state requirements for stormwater permits.

There is a recognized need both nationally and locally to study the role of urban stormwater runoff in relation to water quality. However, before embarking on a full scale NURP Program in Tampa, Phase I was conducted to determine if the existing data base could be used to identify a stormwater related problem and if the stormwater issue should be studied in Tampa.

The conclusions of Phase I summarized in the previous two sections are that the existing data is not sufficient to isolate a direct cause and effect relation between stormwater runoff and water quality, but that available data did indicate stormwater runoff contributed to problems associated with dissolved oxygen, suspended solids, coliform bacteria and heavy metals. Further, the issues related to stormwater runoff can be studied in Phase II of the NURP Project by supplementing the existing data base in the following areas.

1. Pollution characteristics needed to be better defined for urban runoff and other contributing sources, and

2. Receiving water characteristics need to be defined for periods before, during and after storm events.

The main goals in Phase II, in addition to expanding the information regarding pollution loads and receiving water responses to these loads, will be to assess the level of pollution control needed to achieve intended water uses and applicable state standards and to test the effectiveness of selected stormwater controls. The following sections propose a direction to be taken in Phase II of the NURP Program and some of the issues expected in such an undertaking.

Identification of Water Bodies, Drainage Basins, Parameters, and Control Options for Phase II of the NURP Project

Water Bodies and Drainage Basins. It is most desirable to study the impact of urban stormwater runoff where it can be most readily isolated. Therefore, it is important to differentiate among the three receiving water bodies to determine which are best suited for the study of urban stormwater runoff. To do this, each water body is tested against several criteria. An important criteria is the urban area tributary to each water body, as shown below:

Receiving water body	Urban Area, acres	
	Directly tributary	Total
Hillsborough Reservoir	6,000	6,000
Lower Hillsborough River	15,000	21,000
Hillsborough Bay	11,500	32,500

Source: Task 1.3c, Runoff Characteristics

The urban area directly tributary to each water body gives an indication of the relative magnitude of the urban pollution load that will enter the receiving waters during a storm. The urban area directly tributary to the Reservoir and the River discharge stormwater which eventually impacts the Bay. The effect of the total urban area is, however, less than the sum of each part because pollutants are removed or assimilated as water flows through each successive water body.

The objective of the NURP Project is to study stormwater runoff. Therefore, outside factors which interfere with the cause and effect relationship between urban stormwater runoff and resulting changes in the receiving waters should either be eliminated or accounted for. To do this, several criteria which should be considered for each study area are described below:

Point Sources - The pollutant load and flow from point sources impact the water quality conditions being studied and could mask the impact of stormwater runoff. Point sources directly influence water quality only in Hillsborough Bay.

River Inputs - River inputs are a major factor in all of the receiving water bodies in terms of volume and pollutant load. The impact of River flows on the Bay is most complex due to the presence of the Alafia and Palm Rivers as well as the Hillsborough River.

In the Lower Hillsborough River there would be periods, especially during the dry season, when River flows would be small entering the Lower River due to storage behind the Dam and withdrawals by the Water Treatment Plant, This would tend to isolate the impact of urban stormwater runoff in the lower River.

Dredging - Dredging operations can cause local disturbances in the hydraulic and water quality characteristics of the water body. Such conditions must be simulated in order to assess their impacts. During the NURP Project, dredging is expected to occur only in Hillsborough Bay.

Study Area Size and Time Frame - The larger the study area and the longer the time frame to be studied, the more difficult it is to develop well defined cause and effect relationships for stormwater runoff. This is due to the changing nature of the physical, chemical, and biological factors in the system and the increased effort and cost needed to monitor each of these factors as the study area expands and the time frame lengthens. The Bay has the largest study area and would require the longest time period for impact analysis due to its longer hydraulic residence time. The Reservoir may have somewhat longer residence times than the Lower River.

Table 1-4 is a summary of those criteria described above which influence the selection of water bodies best suited for the study of urban stormwater runoff. The results indicate that the effects of stormwater runoff would be best studied in the Lower Hillsborough River, followed by the Reservoir, and the Bay.

In addition to selecting water bodies several urban drainage basins also need to be identified. In these basins, urban runoff will be measured and sampled to quantify flows and pollution loads to the receiving water body. This data will then be used to estimate the quantity of urban runoff coming from the remainder of the study area. As described in the output for Task 1.6b by P-S, three test areas tributary to the Hillsborough River have been selected: one each in the Kirby Street (735 acres), Artic Street (215 acres) and St. Louis Street (325 acres) drainage basins. These basins were selected primarily because there is an exisitng data base, developed by the USGS, which would be expanded upon.

Parameters. Based on Table 1-1, the key parameters for potential study of urban runoff impacts are DO, nutrients, and coliform in Hillsborough Bay, suspended solids and coliform in the lower Hillsborough River, and DO, nutrients, and metals in the Hillsborough Reservoir. These are also the same parameters to be measured in the urban runoff drainage basins as described in the output for Task 1.6b by P-S.

Control Options. Previous outputs described the stormwater control measures available and those most frequently used nationwide (output for Task 1.3a by M&E) and those measures being used in the Tampa area (output for Task 1.5 by the City of Tampa). Based on this background information, the following five control measures were identified in Task 1.6b by P-S for possible testing in Phase II of the NURP program.

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TABLE 1-4. CRITERIA INFLUENCING THE SELECTION OF TEST SITES FOR THE STUDY OF URBAN RUNOFF

	Receiving Water Body		
Criteria	Hillsborough Bay	Lower Hillsborough River	Hillsborough Reservoir
Urban Area Directly Tributary, acres	11,500	15,000	6,000
Major Point Sources	5	0	0
River Inputs	3	1	1
Expected Dredging	Yes	No	No
Approximate Receiving Water Size, sq. miles	40	0.5	1.0
Hydraulic Residence times	months	days	weeks

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- retention-detention ponds,
- grassed swales,
- open bottom catch basins,
- storm sewer exfiltration systems, and
- drainage ditches modified to include retention storage and percolation

With the exception of retention-detention ponds there is little or no data on the effectiveness of these controls. One of the goals in Phase II is to develop data to evaluate individual controls currently in use in the Tampa Area.

Measurement and Sampling Program

Based on the analysis of water bodies, two receiving water measurement and sampling programs are being considered. The most detailed program is for the Lower Hillsborough River since it is the water body best suited for the study of urban runoff. A less detailed program is in the Hillsborough Reservoir. One purpose of the measurement and sampling programs is to verify and supplement the preliminary water quality assessment which was presented in Task 1.3d by M&E. The data would be used to establish cause and effect relationships between stormwater runoff and water quality changes. The data would also be used as input to mathematical models or other analysis techniques that may be used in the receiving waters.

In Table 1-1, water quality parameters were identified which showed adverse trends during wet weather. These parameters will be focused on in the measurement and sampling programs. In addition, data would be collected to fill in gaps for several water quality parameters (eg: metals) and biological parameters.

In addition to those parameters listed in Table 1-1 the water quality assessment also indicated that dissolved oxygen violated state standards in the Lower River, although problems occured mostly during dry weather. The oxygen demanding pollution load from stormwater may contribute to these dry weather problems due to the dissolved oxygen demand from accumulated stormwater related bottom deposits. Therefore, the DO resources in the Lower River will also be studied in Phase II of the NURP Study.

Another important water quality parameter in both the Lower River and Reservoir is visual pollution. Observations would be recorded in the field so a qualitative assessment can be made of pollution such as floatables and debris.

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I. INTRODUCTION

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DESCRIPTION OF NURP

The Nationwide Urban Runoff Program (NURP) was established by the U.S. Environmental Protection Agency for the purpose of developing the knowledge needed to control water pollution from urban runoff. The primary sources of information will be 28 prototype projects located in various cities around the country covering different geographical areas, land uses and water distribution characteristics. The projects will identify urban runoff related pollution problems and evaluate potential control measures. Controls will be evaluated based on pollutant reduction capabilities and cost effectiveness. General methodologies and information developed in these prototype projects will be used by non-participating cities having similar characteristics.

DESCRIPTION OF THE TAMPA STUDY

The City of Tampa, in conjunction with the Florida Department of Environmental Regulation, is participating in the Nationwide Urban Runoff Program. The City's Department of Public Works has a commitment to alleviate flooding problems in the city and maintain water quality standards in the receiving waters. It is the general assumption that stormwater discharges have a detrimental effect on the receiving waters, however, little site specific information is available on the actual effects of these discharges and the potential benefits of pollutant abatement.

Currently, there is a reluctance among local agencies to implement control strategies due to the lack of: 1) a clear understanding of the stormwater pollution sources; 2) information on effectiveness of control strategies; 3) information on the quality of receiving waters and needed pollutant removal levels; and 4) realistic procedures and methods for implementing control strategies. The Tampa NURP Study, along with the other NURP projects will attempt to solve some of these problems.

The City of Tampa NURP study is a three phase project. Phase I of the study will attempt to assess the impact of urban runoff locally by reviewing all available information on local receiving waters and identifying those water segments whose quality is primarily influenced by urban runoff. The objective of Phase II, is to measure and monitor stormwater runoff and water quality, assess the limits of pollution control necessary to maintain acceptable water quality, and test and evaluate alternative stormwater controls. During Phase III, a comprehensive stormwater management plan for the City of Tampa would be developed.

SCOPE OF PHASE I

Reports and results of recently conducted field programs and modeling efforts in the study area, supplied by the City were reviewed during this phase. Hydraulic and water quality characteristics, specifically point and non point sources of pollution were assessed, paying particular attention to cause and effect relationships between wet weather and changes in water quality characteristics for each of the three receiving water bodies. It is important to note that the data collected in the past for the Study Area has been designed primarily to show long term trends and not to show short term wet weather relationships. This condition causes many of the conclusions to be qualified subject to additional data collection in Phase II of the NURP Project.

Hydraulic and water quality models previously used in the study area were also assessed to determine which were best suited to predict expected conditions resulting from urban stormwater runoff. In addition, a detailed review of data was conducted to evaluate the possible cause and effect relation between urban runoff and the biological response of the Tampa Bay system.

REPORT ORGANIZATION

Phase I of the Tampa Study was organized into a number of individual tasks each covering a specific area of the investigation. Responsibility for conducting specific tasks were assigned to either Metcalf and Eddy, Incorporated, Priede-Sedgwick, Inc., or city staff. Task output during the project consisted of a draft report including findings of the task, which were reviewed by the appropriate parties and revised based on written questions and comments. This report presents a compilation of the individual task outputs into a comprehensive Phase I final report. Each technical output is indicated as a section chapter or chapter appendix in this report.

STUDY AREA CHARACTERISTICS

The study area consists of Hillsborough Bay, Hillsborough River below the City of Tampa Dam, and Hillsborough Reservoir as shown in Figure 1-1. Tributary to this interconnected series of water bodies are the upper Hillsborough River watershed, the Alafia and Palm River watersheds, municipal and industrial point sources, and the urban area in the City of Tampa.

The climate in the study area is semi-tropical with hot summers. Maximum daily temperatures in June through September reach 90 deg F. During the remainder of the year, maximum daily temperatures range from 71 deg F in January to 88 deg F in May.

The annual rainfall in the study area is approximately 49.4 inches with about 60 percent falling in the summer months of June through September.

The average wind speed is consistent throughout the year at approximately 8 to 9 mph and is not strongly persistent in any one direction. Generally winds blow east-west in the summer months and north-south during the remainder of the year.

The monthly values for temperature, rainfall and wind speed at the Tampa International Airport are summarized as follows.

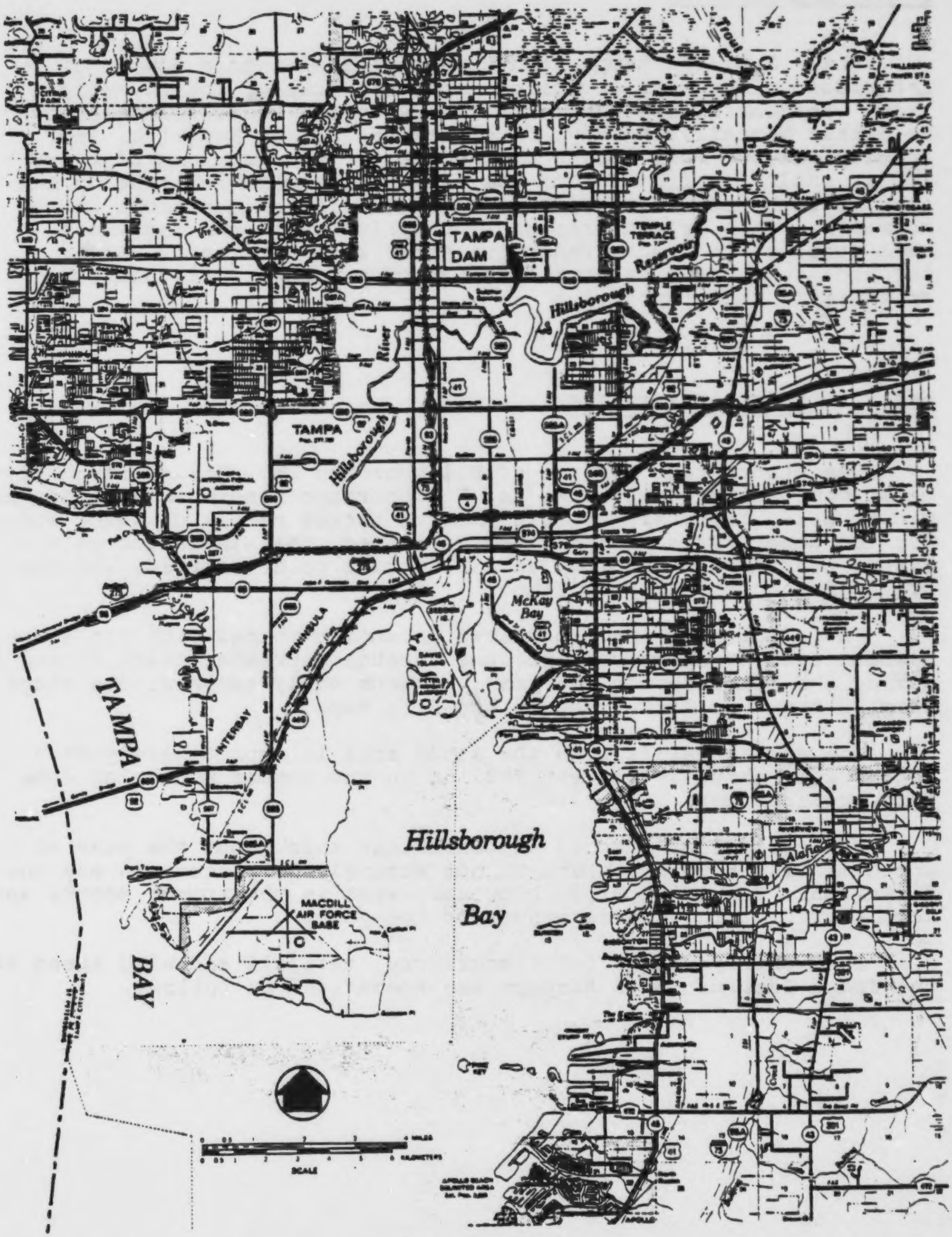
TEMPLE TERRACE
TAMPA DAM
Hillsborough Reservoir
Hillsborough River
TAMPA
Hillsborough
McKay Bay
PENINSULA
INTERBAY
TAMPA BAY
Hillsborough Bay
MACDILL AIR FORCE BASE
SCALE
APOLLO

FIG. 1-1 STUDY AREA

Month	Maximum monthly temperature deg F	Average monthly rainfall, inches	Average monthly wind speed, mph
Jan	71	2.3	8.9
Feb	72	2.9	9.5
Mar	76	3.9	9.7
Apr	82	2.1	9.6
May	87	2.4	9.0
Jun	90	6.5	8.3
Jul	90	8.4	7.5
Aug	90	8.0	7.3
Sep	89	6.3	8.1
Oct	84	2.5	8.9
Nov	77	1.8	9.7
Dec	72	2.2	9.8

NOTE: Data based on US weather bureau records for Tampa International Airport from 1941 to 1970.

The average monthly flows from the three main rivers entering the study area are summarized below.

Month	Average flow, cfs		
	Hillsborough(1) River	Palm(2) River	Alafia(3) River
Jan	240	45	170
Feb	240	45	185
Mar	260	105	190
Apr	160	70	140
May	110	50	75
Jun	175	70	210
Jul	510	95	450
Aug	1,050	150	590
Sept	1,200	115	600
Oct	610	55	315
Nov	240	35	150
Dec	155	35	140

1. Hillsborough River at Tampa Dam (1932-1978).
2. Palm River at State Highway 574 (1956-1960).
3. Alafia River at Lithia (1938-1978).

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II. STORMWATER MANAGEMENT

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Introduction

In 1972, the Federal Water Pollution Control Act Amendments (PL 92-500) had as its aim the restoration and maintenance of the chemical, physical and biological integrity of the nation's waters. One goal of the Act was to establish, wherever possible, water quality suitable for recreational contact and the protection and propagation of fish and wildlife. In moving toward this goal, significant efforts have been placed on controlling municipal and industrial point sources of pollution. As this effort to control "dry weather" point sources has moved forward, more emphasis has been placed on the control of wet weather pollution sources, including urban stormwater runoff. This has been reflected nationwide in the large number of 208 Areawide Water Quality Management Plans that have identified urban stormwater as a significant source of pollution. Management and control of urban runoff is a challenging task due to the unpredictable nature of rainfall occurrences, the large volume of water that is generated in short periods of time, the need for reliable control facilities which operate intermittently, and the competition for valuable urban land often needed for proposed facilities.

Recognizing the complexities involved in controlling stormwater pollution and the absence of data in this field, the Federal government, through the EPA, and local governments have conducted a number of research and full-scale projects designed to test the effectiveness of stormwater controls. Many of these projects are multipurpose in that they serve flood control as well as pollution control needs.

This chapter describes some of the main factors that effect the availability of pollutants prior to and during stormwater runoff, the management practices and controls that have been implemented in some locations to control stormwater pollution, and those practices and controls judged to be most appropriate in the Tampa NURP Project Study Area.

Factors Effecting the Availability of Urban Stormwater Pollutants

Urban stormwater runoff washes accumulated pollutants from the land surfaces into the local receiving water. The result can be a deterioration in water quality. The pollutants originate from a wide variety of natural and social activities and include visual pollution, organic matter, sediments, toxics, bacteria and nutrients. Before discussing the management and control measures used to reduce pollution, it is important to identify the major factors that affect the amount of a pollutant that is available to be moved by urban runoff.

Once the factors that make pollutants available are identified, then measures can be selected to 1) alter the conditions that make pollutants available or 2) remove the pollutants once they have become part of the urban runoff.

The factors affecting the amount of pollution and the extent to which it is washed into local waters are extremely varied. Air pollution, which is primarily caused by motor vehicles and industrial and construction activites can impact the characteristics of urban runoff. Road surfaces have a significant effect on urban stormwater runoff. Pavement types and conditions affect pollutant accumulation: runoff from asphalt pavements tends to be of poorer quality than that from concrete pavements, for example, and impaired pavements can adversely impact street sweeping efficiency. Unpaved streets may contribute to visual and sediment pollution, but can also decrease runoff volume and peak runoff rates. Similar tradeoffs occur between streets with curb and gutters and those with grass swales.

Refuse has an obvious effect on the quality of stormwater runoff. Urban refuse includes discarded rubbish, animal feces, leaves, and miscellaneous wastes associated with urban activities. The frequency and extent of refuse collection, the management of refuse disposal areas and the general public awareness of municipal litter control are important factors in the control of runoff water quality.

Finally, land planning and management, including the surveillance and control of septic tank/leaching fields and landfills, special programs such as mosquito and weed control, the protection of soil against erosion and general municipal maintenance activities, has a significant influence on the extent and types of pollutants swept away with stormwater runoff.

Stormwater Management Practices

Stormwater management practices are divided into two categories for presentation: source controls and discharge controls. Source controls are directed toward removing surface pollutants or reducing their availability before a rain storm occurs. These control consider the factors mentioned in the previous sections and alter them to reduce available pollution. For example, public education programs, cleaning and maintaining drainage ditches, and street sweeping are source controls. Discharge controls change the runoff characteristics or treat the runoff to remove pollutants. Detention ponds, porous pavements and screening devices are discharge controls. Table 1-1 lists the most commonly used stormwater management practices and controls(1)(2)(3)(4)(5).

TABLE 1-1. LIST OF STORMWATER MANAGEMENT PRACTICES

I. SOURCE CONTROLS

1. Public Education Programs
   a. Clean Cities Program
   b. Classroom education programs
2. Community Maintenance Programs
   a. Ditch cleaning and weed control
   b. Litter pickup
3. Catch Basin Cleaning
4. Street Sweeping
5. Street Paving Projects
6. Land Use Planning and Ordinances
   a. Zoning Ordinances
   b. Subdivision Ordinances
   c. Sediment and Erosion Control Ordinances
   d. Pesticide and Fertilizer Control Ordinances
7. Solid Waste Management
8. Animal Waste Removal
9. Air Pollution Control

II. DISCHARGE CONTROLS

1. Storage
   a. Detention ponds
   b. Retention ponds
   c. Underground storage
   d. Parking lot and roof top storage
   e. In-pipe and in-stream storage
2. Percolation
   a. Percolation and recharge basins
   b. Underdrains
   c. Swales
   d. Porous pavement
   e. Open bottom catchbasins

TABLE 1-1 (Continued). LIST OF STORMWATER MANAGEMENT PRACTICES

3. Treatment
    - a. Natural treatment using Cypress stands or marsh area
    - b. Screening
        - Bar screens and coarse screens
        - Fine screens and microstrainers
    - c. Flow concentrators
    - d. Filtration
    - e. Biological and chemical treatment
    - f. Disinfection
4. Diversion
    - a. Diverting first flush to treatment or storage
    - b. Diverting flow to different receiving water or downstream of a sensitive area

---

Source Controls. Source controls are generally non-structural in nature. In the past source controls have generally been evaluated subjectively since data describing their effectiveness is limited and the effectiveness of each can be largely dependent on public acceptance and enforcement. Source controls often have benefits other than water quality improvement and are typically evaluated based on criteria other than water quality improvements. For example, street sweeping can improve the appearance of a municipality as well as improve water quality. There has been a large amount of data gathered on the effectivness of various types of sweepers, different programs, and the amount and kind of material removed. An extensive program of this kind has been conducted in San Jose, California (1). However, there is no data available making the link between street sweeping and improvements in water quality. Therefore, in the past, the measure of success for street sweeping has not been water quality improvements. Again, this is the case with most source controls.

There has also been limited data collected to show the benefit of proper land use planning. However, in the Lake Tahoe area of California and in Texas two programs have been conducted (1) to show the difference between controlled land use planning and uncontrolled development. In the well planned sites, emphasis was placed on the proper siting of structures, and soil and channel stabilization during and after construction activities. In both cases the area with controlled land use planning showed reduced quantities of pollutants in the urban runoff. In the Lake Tahoe case the measure of improvement was suspended solids yield and in the test areas in Texas the measure of improvement was nutrients. Only in the Lake Tahoe case was the analysis taken a final step to show the effect of the reduced sediment loading on the receiving waters. Macroinvertebrates were sampled below each test site in the Lake Tahoe study and conditions were found to be better below the well planned site in terms of number of species, density, and diversity index.

Other selected locations where source controls have been implemented include (1)(3)(5):

Location	Type of Source Control
King County, Washington	Public Education Program
Rochester, New York	Restriction in use of chemicals, fertilizers, etc.
Des Moines, Iowa	Land use controls
Minneapolis, Minnesota	Vacuum street sweeping
Boulder, Colorado	Runoff control ordinance
Stateline, Nevada	Erosion control ordinance
Marlboro, Connecticut	Stream belt zoning regulation
New York, New York	Animal waste ordinance
Bellevue, Washington	Stormwater utility with local financing

In summary, source controls have been implemented in past based on the expectation that they would improve a water quality problem or more likely because they often address other related problems. The type of information developed in the Lake Tahoe study which shows the water quality benefits of implementing proper land use planning is scarce. More work needs to be done before the range of source controls can be quantitatively described in terms of their effect on receiving water quality.

- Discharge Controls. Discharge controls are generally structural in nature. There is operational data describing the performance of many individual controls. However, there is little evidence available supporting a link between the benefits in the receiving waters as a result of stormwater discharge controls. This condition is reflected in the stormwater control plan for Orange County, Florida (1)(2). The plan was created due to the

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need to comply with regional and county regulations and a desire to protect the local receiving waters. The Southern Florida Water Management District requires detention of stormwaters for flood control purposes and Orange County requires the retention of the first inch of rainfall for flood control, erosion control, recharging of groundwater, and prevention of further water quality degradation. The water quality parameters that can adversely impact the lakes and streams in the area have been identified as suspended solids, BOD, total nitrogen and total phosphorus. The stormwater management practices implemented in Orange County to deal with the stormwater quantity and quality issues are listed below:

1. Diversion of the first flush of stormwater to a basin where the captured flow is percolated into the soil.

2. Retention of stormwater and percolation of the captured flow into the soil.

3. Percolation of stormwater in swales and grassed depressions both with and without underdrain systems.

4. Detention-sedimentation basins.

5. Natural treatment of stormwater runoff in Cypress stands.

6. In-line storage using inflatable rubber fabric dams.

7. Street sweeping using vacuum sweepers.

Data was collected for up to nine storms for each control measure describing inflow and outflow characteristics. From a pollution removal standpoint those controls which combined storage and percolation were the most effective, but were also the most costly. Swales, without underdrains and percolation, and vacuum sweeping were effective in removing only suspended solids. In-line storage using inflatable dams was most effective in removing BOD, but required intense maintenance. Natural treatment in Cypress stands was effective in removing all pollutants and was inexpensive. However, this method of control is extremely site specific.

Although all the discharge controls have certain advantages, those which include some combination of detention-retention storage and percolation offer the best removal characteristics for suspended solids, BOD, total nitrogen and total phosphorus.

Storage, in various forms, is the most common stormwater control nationwide. Historically, storage facilities were used for flood control and more recently, for sediment control and control of other pollutants. For this reason many existing and proposed storage facilities are being viewed for the dual use of flood and pollution control.

Adequate data is not available to determine the impact on the receiving waters of the stormwater managment practices in Orange County. This type of data will have to wait until individual controls are implemented on a wide scale in a given drainage basin. This is a common situation nationwide since the management and control of urban stormwater pollution is a new field. Many discharge controls are isolated facilities representing the beginning of an areawide approach to controlling stormwater pollution.

Other selected locations where discharge control have been implemented include (1)(3)(5):

Location	Type of Discharge Control
Gaithersburg, Maryland	Lake storage
Prince Williams County, Virginia Arlington Heights, Illinois Des Moines, Iowa The Woodlands, Texas Boulder, Colorado Bellevue, Washington	Detention basins
Wallingford, Connecticut Davis County, Vermont	Sedimentation ponds
Orange County, Florida Middlesex County, Connecticut	Percolation basins
Denver, Colorado Montgomery County, Maryland.	Rooftop and parking lot storage
Orange County, Florida Reston, Maryland	Grass swales

In summary, the most common stormwater discharge control is storage. Storage can serve the dual purpose of flood and pollution control. For pollution control the two standard approaches are 1) detention with sedimentation and discharge and 2) retention with percolation when soil and groundwater conditions allow.

Although storage is the most common stormwater discharge control, it may not be the best in all cases. More information is needed to 1) quantitatively compare other discharge controls (i.e., treatment) with storage and 2) compare the cost of discharge controls with beneficial improvements in the receiving waters.

Stormwater Management Practices Applicable in the Tampa Urban Runoff Study Area

The City of Tampa has in place a number of stormwater management practices including source controls and discharge controls (6). These are summarized in Table 1-2.

TABLE 1-2. SUMMARY OF PRESENT STORMWATER MANAGEMENT PRACTICES IN TAMPA

Source controls	Discharge controls
1. Maintenance Activities	1. Retention basins
a. Ditch and swale cleaning	2. Detention basins
b. Storm drain cleaning	3. Underground storage
c. Retention-detention pond cleaning	4. Open bottom inlets
2. Street sweeping	5. Swales
3. Catch basin cleaning	
4. Street resurfacing	
5. Curb construction	
6. Soil and erosion control ordinance	

In order to look at the condition in the Study Area there are two categories to address. One is those areas to be developed and one is those areas already developed. In areas to be developed the first and most important step in stormwater control is environmentally sound land use planning. Such planning consists of proper siting of buildings, minimizing impervious areas connected directly to receiving waters, and taking advantage of natural storage and flow patterns. This type of planning should be supplemented by on-going maintenance and good housekeeping procedures.

In the Tampa Urban Runoff Study Area the majority of the land is already developed. Although this minimizes the effect of land use planning, efforts can still be made on a case by case basis to maintain natural channels and open space. The main opportunities to control pollution from urban stormwater runoff in the developed areas of Tampa include:

1. Source controls which reduce the amount of pollution available for transport into receiving waters and which normally do not require land taking.

2. Maintaining open space and a drainage network that takes advantage of natural open space for temporary storage.

3. Storage for individual building sites and for small drainage basins. This includes dual use of existing flood storage facilities to include pollution control.

4. Percolation of stormwater in areas where soil and groundwater conditions permit. This can range from individual catchbasins to retention storage area.

5. Screening and grit chambers at stormwater discharge locations.

Table 1-3 lists these categories of best management practices and the pollutants they are most likely to effect. Of the five categories listed in Table 1-3 Tampa presently places emphasis in three: source controls, storage, and percolation. These are the three areas where testing is most likely in Phase II of the Tampa NURP Project.

TABLE 1-3. ABATEMENT OF POLLUTANTS BY BEST MANAGEMENT PRACTICES

	Pollutants effected by each BMP					
Best Management Practice	Organic matter	Sediments	Visual	Toxics	Bateria	Nutrients
Source controls	X	X	X	X	X	X
Maintaining open space	X	X	X			
Retention storage	X	X	X			
Percolation-retention storage	X	X	X	X	X	X
Screening and grit removal		X	X			

Stormwater Management Practices currently used in Tampa

The City of Tampa Department of Public Works (DPW) is responsible for the majority of drainage activities conducted within City limits. Structural controls such as rentention/detention basins have been common in Tampa for the past several decades but until recently have been built only as volume control facilities. Maintenance of the drainage system (i.e., ditch cleaning, catch basin cleaning, detention/retention pond maintenance, street sweeping, etc.) has also been practiced to help alleviate flooding problems. Many of the management practices and structural controls available locally are now under consideration by the U. S. Environmental Protection Agency (EPA) for the abatement of pollutants in urban runoff. Knowledge of existing structural control facilities and maintenance activities should be useful in the selection of test basins for Phase II of the NURP study. A description of the various practices considered to have a potential impact on the reduction of pollutants in urban runoff follows.

Structural Controls

The most common structural storage/percolation controls are retention and detention basins. More recently, open bottom inlets and underground drain fields are being incorporated into new storm sewer designs. Swales, once a common method of draining residential roadways, are now utilized less frequently in new designs as adequate space if often unavailable in much of the City'shighly urbanized areas. However, one recently designed drainage project did make substantial use of swales as a menas for controlling both the quantity and quality of runoff.

Retention/Detention Ponds. The City has incorporated retention/detention basins into drainage designs since the 1940's. These ponds reduced the need for larger drainage systems and thereby reduced costs. However, in basins close to natural receiving waters, runoff was piped or ditched directly to the water bodies.

Detention basins built in the past five years are usually designed to empty over approximately 24 hours by incorporating low-capacity bottom drains. High-capacity overflow structures designed to accommodate flows beyond the accumulation of the 25 year event, reduce the possibility of basin over-topping. Retention basins have been given literature values that range from poor to extremely good for removal of suspended solids and BOD; while nutrient removal is generally considered low. The City of Tampa has not monitored water quality attenuation on discrete basins.

Retention basins are used only sporadically and rely upon percolation and evapotranspiration to dispose of the accumulated stormwater. Two recurrent problems limit their use: sedimentation and high groundwater levels. Sedimentation gradually reduces the storage capacity, and fine sediment hinders infiltration. High groundwater levels preclude retention basin use in many areas of the City. The hydraulic head differential is so small in most areas that percolation is exremely slow. However, retention basins are used in areas with deep, well-drained sands, which are usually associated with relic shoreline/beach dune terraces.

Detention/retention basins can remain wet throughout the year. These wet basins are usually artificially created, however, some natural karst or wetland features have been utilized as basins. Water depth varies with rainfall, antecedent conditions, and depth to the watertable. Several basins, because of shallow depth, have developed rooted and emergent aquatic vegetation. Maintenance of these shallow basins can be difficult and costly. Stagnant, shallow basins with lush aquatics often provide excellent habitat for mosquitoes, and are considered by the Hillsborough County Mosquito Contrl Department to be public nuisances. Permanently wet ponds, if not overcrowded with vegetation, can support fish populations which will naturaly prey on mosquito larvae and thus keep adult mosquito populations under control. Although a dense growth of aquatic vegetation is effective in removing nutrients, it can seriously reduce the capacity of the basin and lead to accelerated sedimentation. Conversely, the deeper basins which do not support extensive vegetation are also considered public nuisances because of the potential drowning hazard. The effectiveness of pollutant removal between the wet vs. dry and retention vs. detention basins in Tampa has not been measured.

Open Bottom Inlets. Open bottom inlets were recently constructed in the Sulphur Springs area, specifically to reduce stormwater pollutant loads (Fig. 1). When filled to the point where flow begins, the storage capacity is approximately 85 cubic feet, including infiltration into the soil. Desk-top estimates of pollutant reductions due to the open-bottom inlets are conservative in that no pollutant capture is assumed to occur after the storage capacity in each inlet is fully utilized (which could take place within five or ten minutes after the start of a heavy rainfall). In actuality, the ponding of storm water in each catch basin will encourage the settling out of particulate pollutants during the entire course of a storm event. However, no monitoring has been done to verify predicted loads.

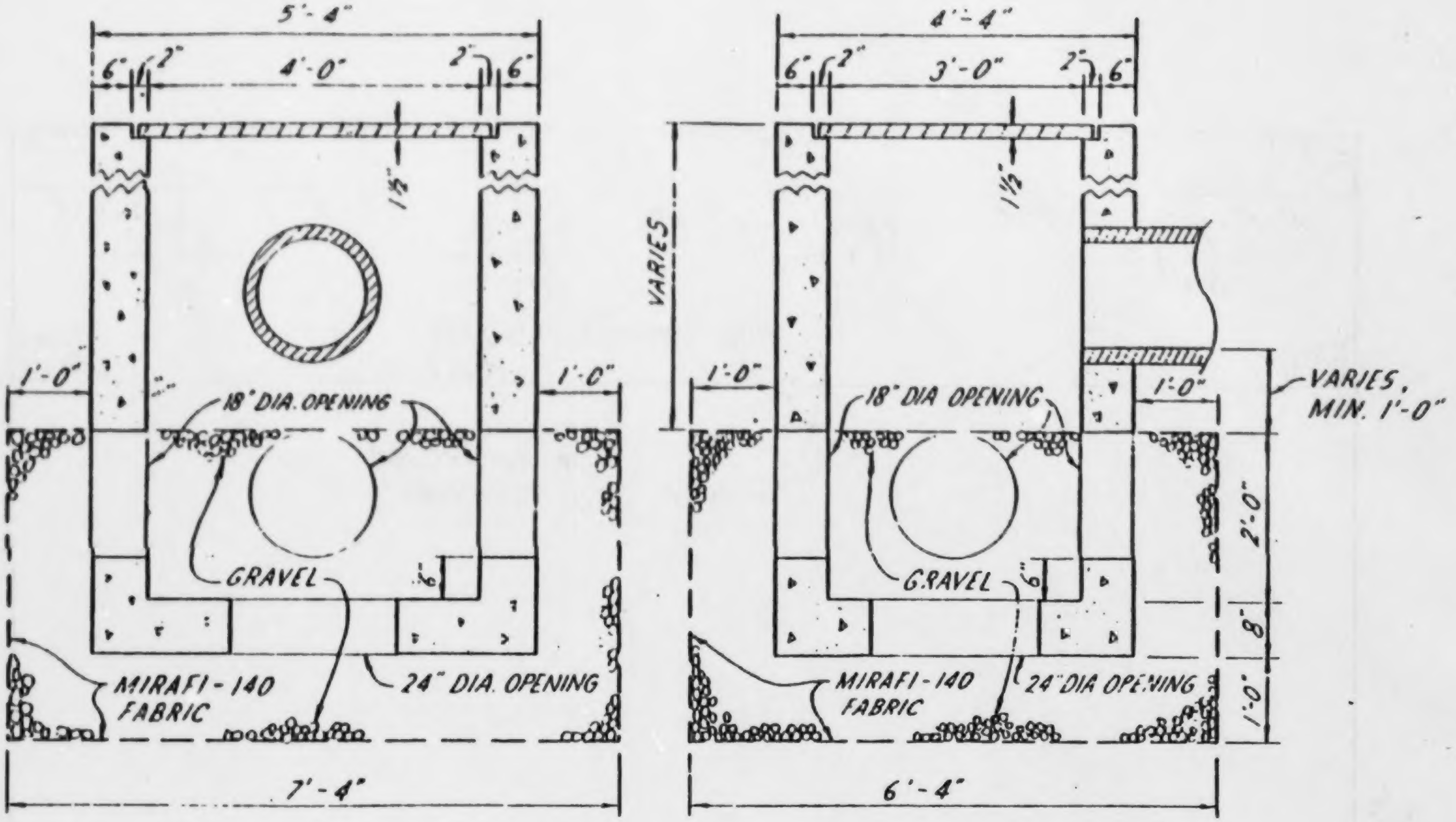
Underground Storage. Underground drainfields, percolation trenches, and open-bottom inlets are planned in another storm sewer project in the Sulphur Springs area (Fig. 2). Perforated pipe will be imbedded in gravel beds with a void space ratio of about 0.4. The trench is then topped with dirt. Estimates of removal efficiencies are high (See Table 1).

Swales. Roadside swales are often seen in older neighborhoods. Evaluating the effectiveness of swales as a pollution control measure is difficult, especially during times of low-flow. The limiting factor associated with swales is the regular maintenance necessary to ensure unrestricted flow, and to reduce the possibility of mosquito breeding.

In summary, some of the most often mentioned structural control mechanisms are utilized by the City. Most, however, have not been locally field tested as pollutant abatement mechanisms, and many in fact were installed as flow attenuation devices, or as a cost-savings measure.

Maintenance Activities

The City's various maintenance activities could have a tremendous impact on the quality of urban runoff. Each activity is usually conducted on a regular basis, with service levels based upon available manpower, citizen complaints, aesthetics, and pollution control reasons. It is extremely important that control measures rcommended in Phase III of this study be economically feasible. Implementation of such controls will be assured locally and nationally if only minor municipal budget modifications are necessary. Given a better allocation of existing resources, the City's maintenance program could be used as a positive means for managing runoff, both quantity and quality aspects.


5'-4"
6"
2"
4'-0"
2"
6"
1½"
1'-0"
1'-0"
18" DIA. OPENING
GRAVEL
6"
MIRAFI-140
FABRIC
24" DIA. OPENING
7'-4"
4'-4"
6"
2"
3'-0"
2"
6"
1½"
VARIES
1'-0"
18" DIA OPENING
1'-0"
VARIES,
MIN. 1'-0"
2'-0"
GRAVEL
6"
8"
MIRAFI-140
FABRIC
24" DIA OPENING
1'-0"
6'-4"

SECTION A-A

SECTION B-B

FIGURE 1. Open Bottom Inlet

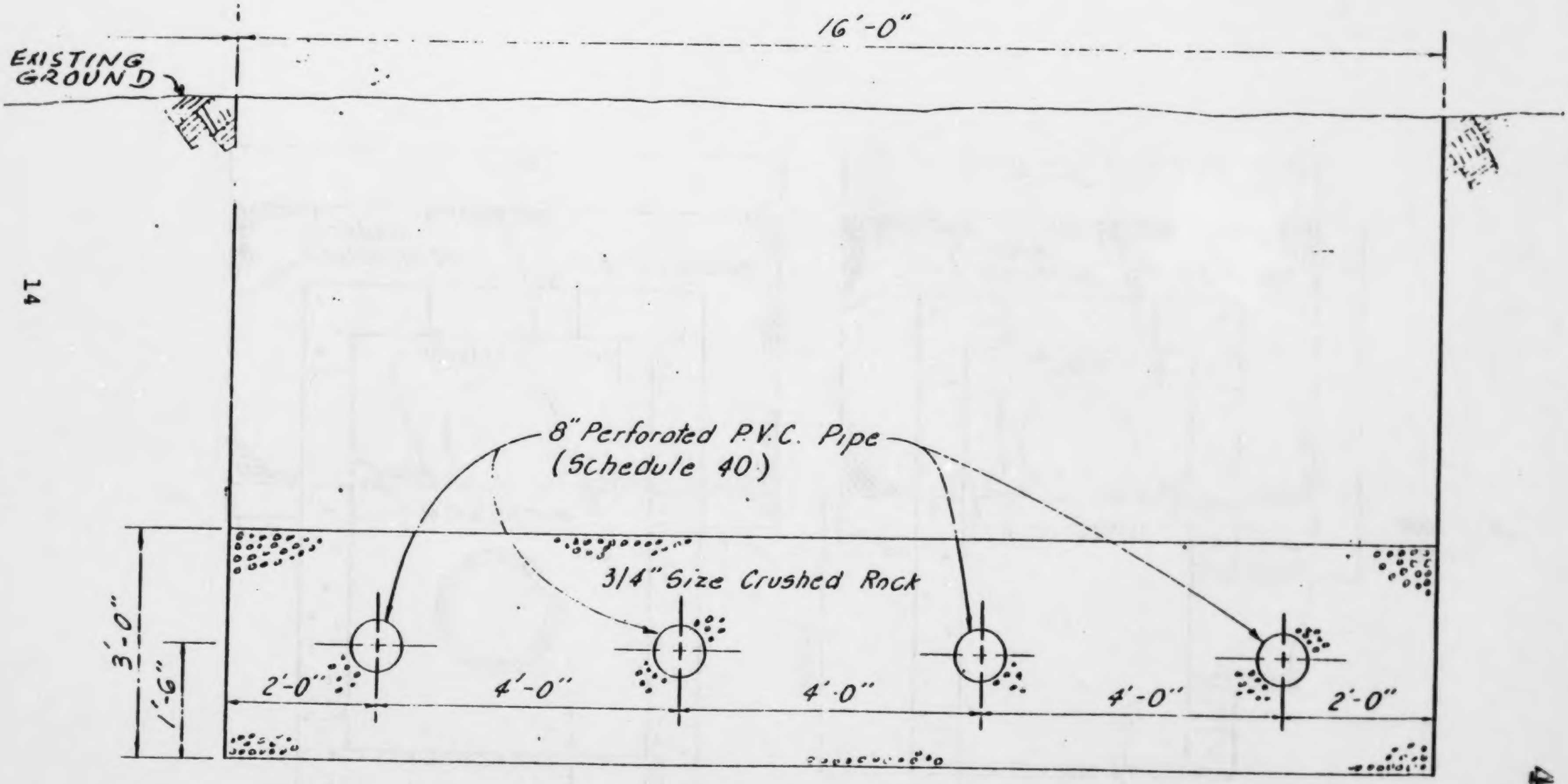

16'-0"
EXISTING GROUND
8" Perforated P.V.C. Pipe
(Schedule 40)
3/4" Size Crushed Rock
3'-0"
1'-6"
2'-0"
4'-0"
4'-0"
4'-0"
2'-0"

FIGURE 2. Cross Section of Drainfield

TABLE 1-4

POLLUTANT LOADINGS UNDER THE INFILTRATION TRENCH ALTERNATIVE

	ANNUAL LOADINGS IN POUNDS PER YEAR			
	BOD	SS	NITROGEN	PHOSPHORUS
Present Loadings	2,204	49,892	250	59.2
Loadings with Storm Sewers and No Pollution Controls.	3,094	70,042	351	83.1
(Increase Due to Storm Sewers)	(890)	(20,150)	(101)	(23.9)
Reductions Due to Pollution Controls:				
Open-Bottom Inlets.	92	1,706	9.5	2.2
Drain Field	249	4,616	25.7	6.1
Infiltration Trenches	1,178	21,821	121.5	28.8
(TOTAL)	(1,519)	(28.143)	(156.7)	(37.1)
Loadings with Storm Sewerage and Pollution Controls.	1,575	41,899	194.3	46.0
Percent Change in Loadings Due to the Project With Controls	-28.5%	-16.0%	-22.3%	-22.3%

Source: Environmental Science and Engineering, 1978.

The City of Tampa contains 84.45 square miles of land area, with 2,720 lane miles of paved streets. Approximately half of the land area is drained by an underground storm sewer system; the balance is drained by an open ditch system or has no specific drainage system. Some of the drainage system is affected by tidal action. There are almost 10,000 inlets in the storm sewer system and 200 miles of ditches. The City is characterizd by numerous spot flooding areas due to inadequate or non-existent systems, and a less than adequate consideration for land use changes.

Ditch Maintenance. Ditches are maintained on a semi-annual basis to provide free flow and acceptable aesthetic conditions. This includes mowing all vegetation, removing all objects which could obstruct the flow of water, and applying an herbicide to control growth. Ditch maintenance crews are dispatched primarily in response to complaints regarding the appearance of ditches. The City receives numerous complaints daily on the condition of ditches, particularly during the rainy season.

In an effort to better manage this activity, a ditch system inventory has been prepared (information is available on location, type, dimensions and access characteristics) and new equipment (slope mowers, etc) has been acquired with improved productivity levels.

Most ditches have not been graded in several years. Dirt and debris have accumulated on the bottom of the ditches, resulting in a reduction in both holding and routing capacities for runoff. The City has ordered equipment (Ditch-Master) which will permit the regrading of the majority of ditches at the rate of one mile per day.

Map A identifies all ditches and canals in the City. Map B shows the access characteristics of the ditches. Only those ditches not easily accessible to heavy equipment appear on Map B. The majority of ditches are easily accessible to heavy equipment and these areas could be applicable as test sites (i.e., regrade ditches to allow for greater detention time, clean at a level to permit maximum vegetative treatment of runoff, etc.).

Swale Maintenance. Very little imformation is available on the location of swales. Mowing of swales is the property owner's responsibility. Regrading of swales is the City's responsibility.

Storm Sewer Maintenance

Results obtained in a sample survey of City streets conducted in July, 1978, estimate the present inventory of storm sewers as 106 miles of major pipes (greater than 24 inches) and 176 miles of minor pipes (less than 24 inches). Map C shows the major storm sewers and drainage basins in the City.

Storm sewers are cleaned on an as needed basis. City crews use a hydrojet or bucket equipment. The hydrojet forces water through the sewer, flushing all materials from the bottom of the pipe. This water is then intercepted before it reaches the receiving water body. Bucket equipment is used to scrape the storm sewer and remove debris from the bottom.

Inlets are cleaned at a mimimum, on an annual basis. Many are cleaned as often as four times a year. Inlets are presently cleaned manually, however, DPW is acquiring equipment (vacuum assisted hydrojets) which will remove all material trapped in the sump. Street sweeping equipment also has attachments which allows for vacuuming inlets.

Street Resurfacing Program

The City has a substantial street resurfacing program and has made committments to conduct some of this resurfacing in concert with other control measures (open bottom inlets) in a recently permitted drainage basin . Pollutant concentrations have often been tied to street surface conditions (i.e., streets with rough surfaces jar contaminants from automobiles; loose gravel and dirt adds to sediment discharge to receiving waters, etc.). The City plans to resurface 40 miles of street this year with asphaltic concrete and seal with an asphalt slurry an additional 40 miles.

The City is also characterized by 160 lane miles of brick streets (see Map D) and is in the process of adopting a policy to preserve most of these streets.

Retention Pond Maintenance. There are more than 75 retention ponds within City limits (see Map E). These ponds are designed to 1) detain runoff and discharge as needed, 2) detain runoff for a short time and then release as positive outfall, or 3) retain runoff permanently.

Retention ponds are mowed three times a year. Pond bottoms are disced with a tractor when needed. Ponds are also sprayed with an oil product for mosquito control.

Street Sweeping. The City has approximately 1,200 miles of curb (see Map F). The street sweeping fleet presently is composed of three vacuum sweepers (VacAlls) and three mechanical brush sweepers (Elgin Pelicans and Wayne Mechanicals). The City anticipates delivery of two additional vacuum sweepers (Elgin Whirlwinds) shortly, at which time the three mechanicals will be used only on an as needed basis.

A review of the street sweeping literature was recently conducted. Little information was found on aesthetic service levels and little conclusive information was found on the environmental effects of street sweeping. However, Robert Pitt, in his study of street sweeping in San Jose, recommended a concentrated sweeping effort on streets typically characterized by high pollutant loads (i.e., streets with industrial and commercial land use, high traffic volumes, poor surface conditions, etc.). He found mnimal environmental benefits from a residential sweeping program. These findings have been incorporated into the recently revised sweeping program, which follows:

1. All commercial, industrial, and heavily traveled streets (see Map G) will be swept twice a week.

2. Residential streets will be swept as needed.

3. Vacuum sweepers will be used on commercial routes.

Further modifications to the sweeping program are anticipated as follows: 1) Eliminate sweeping in rainy season, 2) increase sweeping frequency in residental areas during leaf season, and 3) clean inlets frequently during rainy season.

Asphalt Curb. In order to prevent erosion, asphalt curbs are constructed in problem areas. Approximately 20,000 linial feet of curbs are placed annually. These curbs are generally not included in the sweeping program.

Erosion Control

The City of Tampa recently passed an ordinance requiring erosion and sediment control structures to prevent adverse effects to the environment and public and private property. These requirements do not apply to sites less than one-quarter acre (see attached ordinance).

Site Drainage Plans

Construction activities in the City of Tampa must be permitted by the Department of Public Works. Included in this permitting procedure is the review and approval of site drainage and grading plans. Information to be included in the plan includes topographical and design data sufficient to show no drainage damage to adjacent property. Also, minimum elevations for living space are cited. In addition, the permitting office cooperates with the Florida Department of Environmental Regulation in the review of many construction plans.

Other Potential Controls

Portions of the Port of Tampa are characterized by deep channels, many of which are adjacent to storm water discharge outfalls. These channels have poor water quality and silty bottoms and undergo regularly scheduled maintenance dredging. It has been suggested by one local agency that such channels could serve as sinks for certain stormwater pollutants and that they therefore be considered more often as receivng bodies for stormwater discharges.

LIST OF MAPS

Available on Request;
City of Tampa, Department of Public Works

A. Map of Ditches

B. Map of Ditches by Access Characteristics

C. Map of City Storm Drainage

D. Map of Streets Paved with Bricks

E. Map of Stormwater Retention Areas

F. Map of Curbed Streets

G. Map of Street Sweeping Service Area

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III. NON POINT SOURCE POLLUTION

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SECTION 1

INTRODUCTION

This report summarizes the preliminary estimates of the urban runoff volumes and pollutant loads generated in the Tampa Urban Area which drain to the Reservoir, the Lower Hillsborough River, and the Hillsborough/McKay Bay system. These estimates are based on multiple regression analyses of hydrologic response and pollutant load information performed by the United States Geological Survey during their Tampa Bay Area urban studies.

The portions of the Tampa Urban Area which have been described above have been divided into thirteen urban basins and have been analyzed as shown in Figure 1-1, an idealized model of the study area.

The Report is divided into five separate sections and one appendix. Section One consists of the Introduction and Section Two briefly describes local studies which are pertinent to the estimation of hydrologic and pollutant loads. Sections Three and Four summarize the methodology and the resultant hydrologic flows and volumes, and select pollutant loads for typical wet and dry months. Section Five contains interpretations and observations concerning the individual and cumulative meaning of the various loads. Precise techniques, intermediate values, and value ranges are described in detail in the Appendix.

SECTION 2

PERTINENT LOCAL STUDIES AND DATA

Prior to the commencement of the USGS Urban Runoff Study in 1975, limited systematic study of urban runoff characteristics had been undertaken in the Hillsborough River/Hillsborough Bay system. Generally, the majority of studies pertaining to Hillsborough River have dealt with runoff quantity in tributary basins. The principal objective of these investigations has been removing the water from the land surface and conveying the flows into the receiving waters, i.e., the Hillsborough River.

With increased environmental concern directed toward the reservoir and the advent of stormwater discharge permits, water quality considerations have attracted greater attention. The earliest water quality monitoring program, conducted by the City of Tampa Water Department, was interested in monitoring parameter trends which affected water treatability at the plant. Subsequent changes in drinking water standards and aquatic weed control methods increased the frequency and number of analyses conducted by the Water Department.

Federal, State and local agencies (United States Geological Survey and Environmental Protection Agency, the Florida Department of Environmental Regulation, and the Hillsborough County Environmental Protection Commission) began to sample and monitor the water quality in the Hillsborough River/Hillsborough Bay System on a periodic basis. As this data began to accumulate, these agencies and the academic/scientific communities began to interpret the trends and meanings of this new water quality information.

Based upon the project team's review of the reports generated on urban runoff, water quality, quality and movement in the Tampa Bay Region, very few specifically and comprehensively address the topic of urban runoff quantity and quality. Briefly described in the following paragraphs are those local studies pertinent to this topic.

1. Anderson, M.W. and B.E. Ross, The Effect of Urban Land Development on Water Quality, University of South Florida, Tampa, Florida, August 1975.

The primary purpose of this project was to determine the magnitude of the changes in the quantity and quality of stormwater runoff from a small urbanizing watershed, which is located immediately upstream of the Hillsborough River Reservoir. Unfortunately, the anticipated development did not take place, thus changes did not occur. However, information was obtained pertaining to the quality of runoff from a partially developed watershed and how this quality varies with time during a storm. Rainfall gages, an evaporation gage, and flow measuring devices were installed within the watershed area, from which daily hydrologic data were obtained. In addition, water quality measurements were taken at the drainage exit of the study area. The parameters measured were dissolved oxygen, pH, carbon dioxide, temperature, hydrogen sulfide, color, turbidity, metaphosphate, orthophosphate, nitrate, nitrite, and coliform count. Shallow aquifer test wells were installed and monitored in order to establish ground water flow directions, ground water storage changes and ground water quality changes.

2. Copeland, C.E., The Prediction of Stormwater Runoff Quantity and Quality for the Tampa Bay Region, University of South Florida, Tampa, Florida, August 1973.

The purpose of this study was to develop a modeling technique which would indicate the magnitude of change in the quantity and quality of stormwater runoff from a given drainage basin as it is developed. By varying land use patterns according to population forecasts, this technique could be used to determine which areas could be developed with the least impact on the quality of receiving waters. Water quality predictions made through this modeling technique were not meant to be the exact concentrations that would be determined from point samples in the field, but rather temporal and space averages which indicate long-term trends which would be expected, with assumed development patterns.

3. Cureton, D. and T. Locicero, Research of Hillsborough River Water Quality, University of South Florida, Tampa, Florida, March 1976.

A student project which correlated water quality parameters for samples collected in the Hillsborough River Reservoir including BOD_5, hardness, and color with other basin environmental and physical factors such as rainfall, population and construction activity. The bivarient and multivarient analyses of these factors proved to be generally inconclusive.

4. Hagan, J.E., Problems and Management of Water Quality in Hillsborough Bay, Florida, Tampa, Florida, December 1969.

The objectives of this study were: (a) identify and quantify key sources of waste in Hillsborough Bay; (b) determine the causes of noxious odors in the Bay; and, (c) recommend methods of modifying these problems. Identification and evaluation of key waste sources required sampling each tributary stream as well as municipal and industrial waste sources. Determining the effects of these wastes on water use required water quality measurements throughout the Bay system involving the following special studies: water quality field surveys over several short periods of time to define equilibrium conditions; synoptic chloride and temperature studies; dye tracer and tidal current measurements; mapping and chemical characterization of benthic materials, and primary productivity studies. Recommendation of abatement procedures required consideration and evaluation of a wide array of alternatives. These alternatives were evaluated using a mathematical simulation of the bay system to gain insights into the probable effects of the abatement actions on resultant water quality and environmental conditions.

5. Shearer, J.S., Stormwater Quality from a Residential-Commercial Drainage Basin, University of South Florida, Tampa, Florida, August 1973.

A student report describing the water quality of stormwater from a residential-commercial basin in Temple Terrace which discharges to the Hillsborough River Reservoir. Grab samples were collected for three storms, analyzed by colorimetric methods (HACH Kit), and compared with time--not flow. Estimates of the total pollutant load were prepared based on observed time of concentration and basin physical characteristics.

6. Tampa Bay Regional Planning Council, Non-Routine Water Quality Sampling, St. Petersburg, Florida, November 1976.

During August, September, and October, 1976, field teams conducted a wet season storm event sampling program designed to quantify base flow and stormwater runoff pollutant mass loadings and to determine the severity of problems associated with septic fields and old phosphate mines. This period, unfortunately, was one of the driest wet seasons in the recent history of the region. As a result, the sampling program generated far less data than had been desired.

The program was designed to sample storm runoff from a variety of land use categories for the purpose of calculating mass loadings. Due to physical constraints it was not possible to sample runoff from each of the land use categories utilized in other parts of this study. Instead the decision was made to characterize the runoff from broader land use categories that represent an aggregation of more detailed land uses. The land uses included mixed suburban, urban, impervious surfaces, bedded citrus groves, pasture, and septic tank fields. An attempt was made to sample at least two storm events at each site.

Data are very limited and not generally useful in evaluating season variations in pollutant loadings.

7. United States Geological Survey, Urban Stormwater Data and Studies.

The USGS has undertaken urban studies in Miami and Tampa, Florida. These studies identified urban runoff quantity and quality for homogenous and heterogenous land use basins. The Miami studies concentrated on four single land use basins while the Tampa studies targeted nine mixed land use basins. Both studies have produced extensive runoff quantity and quality data which has been published in five data reports. This data was analyzed to derive an algorithm to predict the quantity and quality of urban runoff when physical basin characteristics and precipitation event sequences are specified. The Miami study currently is being published, while the Tampa study is presently being prepared for publication.

Basic Data Studies:

a. "Hydrologic Data from Urban Watersheds in the Tampa Bay Area, Florida", WRI 78-125.

b. "Urban Stormwater Runoff Data for a Residential Area, Pompana Beach, Florida", OFR 78-324.

c. "Stormwater-Runoff Data for a Highway Area, Broward County, Florida", OFR 76-612.

d. "Stormwater-Runoff Data for a Commercial Area, Broward County, Florida", OFR 79-982.

e. "Stormwater-Runoff Data for a Multi-family Residential Area, Dade County, Florida", OFR 79-1295.

Data Analysis Studies:

f. "Analysis of Urban Stormwater Quality from Nine Basins in the Tampa Bay Area, Florida", WRI 80-XXX, discussions of a report in preparation.

g. "Analysis of Urban Stormwater Quantity from Nine Basins in the Tampa Bay Area, Florida", WRI 80-YYY, discussions of a report in preparation.

h. "Analysis of Urban Stormwater Quality from Three Basins in Broward County, Florida", WRI 80-ZZZ, discussions of a report in preparation.

SECTION 3

URBAN RUNOFF QUANTITY

Introduction

In order to characterize pollutant loads attributable to urban runoff, specific variables impacting stormwater flows must first be identified. In addition to the quantity of rainfall attributable to a given precipitation event, other site specific factors must also be quantified. Land use patterns directly influence runoff quantity through effecting the time of delivery (time of concentration) and the quantity of water delivered (impervious areas) to a stream system. The number of dry days preceding a storm event (antecedent period) is also important in defining the quantity of stormwater delivered from a given drainage. Preceding and specific values utilized for generating urban runoff quantities are presented in this section with supportive detailed methodology presented in Appendix A.

Precipitation

Since precipitation is the principal function driving runoff generation, available precipitation data must be evaluated to determine both short-term and long-term trends. Data collected at the Tampa International Airport by the National Oceanic and Atmospheric Administration have been used in this analysis. Figure 3-1 illustrates the variations in annual precipitation values for the last twenty years (1960-1979). The mean annual value for the period of record is 48.82 inches. Figure 3-1 also shows the annual deviation from normal for each year.

In recent years, annual precipitation values have been substantially below normal. The period 1961-1978 (inclusive) has displayed an average annual deviation from normal of (-)6.75 inches with a cumulative deviation from normal of (-)121.56 inches--approximately equivalent to 2.5 years of normal precipitation.

Precipitation data from 1949, 1955, and 1973 were selected as representing an average year's precipitation and were used for purposes of evaluating typical rainfall events and frequencies. The following table indicates that these years are within ±2 percent of the mean annual precipitation value for the Tampa station.

Year	Precipitation* (in)	Deviation* (in)	Deviation (%)
1949	48.24	-0.58	-1.19
1955	48.81	-0.01	0.02
Mean	48.82	0	0
1973	49.71	+0.89	+1.82

Individual months in these years were evaluated to determine the two months which best represent a typical "wet" month and a typical "dry" month. The months selected were May, 1949, and November, 1955, for the dry season and June, 1949, and September, 1955, for the wet season. Precipitation amounts and distribution for each calendar day for these representative months are contained in Appendix A.

Urban Basin Analysis

The Tampa Urban Area, including the City of Temple Terrace and portions of Hillsborough County, was divided into three major drainage areas designated as follows:

- Hillsborough River Reservoir - Those areas which drain to the river between the bridge at Fowler Avenue and the City water supply dam. This area was sub-divided into four urban basins with two basins on each side of the river and a division point on the river approximately located at the 56th Street Bridge.

- Lower Hillsborough River - Those areas which drain to the river between the City dam and the mouth of the river. This area was divided into six urban basins with three basins on each side of the river and division points along the river approximately at the Buffalo Avenue bridge and the Interstate-75 river crossing.

- Hillsborough Bay - Those urban areas which drain directly to the Hillsborough Bay/McKay Bay system. This area was divided into the following three urban basins: the Interbay Pennisula draining to Hillsborough Bay; Davis and Seddon Islands, the Maritime Boulevard Penninsula/Port area, and those portions of the Downtown area which drain to Hillsborough Bay; and those contiguous urban areas of Tampa and Hillsborough County located north, northeast, and east of McKay and Hillsborough Bays which drain to the Bay Systems. These areas and the thirteen urban basins are delineated on Figure 3-2.

Land use data obtained for these areas from The Tampa Comprehensive Plan 2000 was aggregated into three general land use classes: developed, residential, and natural. Sizes and land use distribution for the three major drainage areas are:

		Land Use Distribution		
	Area (acres)	Developed (%)	Residential (%)	Natural (%)
Reservoir	8,017	17.2	57.2	25.6
Lower River	16,898	10.1	80.9	9.0
Bay System	16,753	27.5	42.1	30.3
Tampa Urban Area	41,688	18.5	60.8	20.8

Hydrologic Response Analysis

The urban hydrology data base developed by the United States Geological Survey (USGS) during their 1975-1980 Tampa Bay Urban Area Study was examined utilizing multiple regression methodology to determine predictive load models for base flow, storm peak flow, and runoff volume. A statistical analysis system developed at North Carolina State University (SAS 76) was used by the USGS to perform stepwise multiple regression and associated calculations. The stepwise regression procedure was used in the analysis of the urban hydrographs for their nine urban basins. This procedure examines the contribution made by each basin characteristic and meterological factor at every step. The three predictive models utilized for determing base flow, storm peak flow, and storm runoff volumes were:

$$\text{Base Flow} = 0.37(\text{DA})^{1.18}(\text{TRF}+1)^{2.73}(\text{ANT}_{14}+1)^{0.55} \ \text{cfs}$$

$$\text{Storm Peak Flow} = 14.45(\text{DA})^{0.57}(\text{EIA})^{0.61}(\text{TRF})^{0.75}(\text{ANT}_2+1)^{0.20} \text{cf}$$

$$\text{Storm Runoff Volume} = 1.32(\text{DA})^{1.14}(\text{EIA})^{0.71}(\text{TRF})^{1.13}(\text{ANT}_1)^{0.19} \ \text{acre-}$$

where:

DA = drainage area (sq.mi.)

TRF = total daily rainfall (in.)

EIA = effective impervious area (sq.mi.)

ANT_1 = antecedent 1-day precipitation (in.)

ANT_2 = antecedent 2-day precipitation (in.)

ANT_{14} = antecedent 14-day precipitation (in.)

The predictive models developed by the USGS were applied to the urban basins for two months of representative precipitation events occurring in the wet and dry seasons. The hydrologic responses predicted by the models were anlyzed to determine representative response characteristics for a "typical" wet and dry month and with the results summarized in Table 3-1.

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TABLE 3-1: TYPICAL WET AND DRY SEASON URBAN RUNOFF HYDROLOGIC RESPONSES FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA

	Wet Month	Dry Month
Directly to Hillsborough River Reservoir:		
. Daily Base Flow (cfs)	14.5	8.9
. Storm Peak Flow (cfs)	46.7	47.3
. Storm Runoff Volume Per Event (acre-ft.)	2.8	3.0
. Cumulative Monthly Runoff (acre-ft.)	908	545
Directly to Lower Hillsborough River:		
. Daily Base Flow (cfs)	32.4	19.8
. Storm Peak Flow (cfs)	109.4	110.5
. Storm Runoff Volume Per Event (acre-ft.)	16.0	17.3
. Cumulative Monthly Runoff (acre-ft.)	2150	1240
Directly to Hillsborough Bay:		
. Daily Base Flow (cfs)	30.4	28.4
. Storm Peak Flow (cfs)	137.9	139.6
. Storm Runoff Volume Per Event (acre-ft.)	6.7	7.5
. Cumulative Monthly Runoff (acre-ft.)	1920	1730

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USGS mean monthly discharge values for the Hillsborough River into the reservoir have been analyzed for wet and dry months. The results of this analysis, in terms of estimated flow rates and volumes are as follow:

Discharge Measured at Fowler Avenue Bridge:	Typical Monthly Values	
	Wet Month	Dry Month
. Mean Monthly Flow Rate (cfs)	668	178
. Mean Monthly Flow Volume (acre-ft)	40,400	10,700

Additionally, USGS mean monthly discharge values for the release at the dam to the lower river have been analyzed for both wet and dry months. This discharge, it must be noted, is controlled by the Water Department based on reservoir volume, water supply needs and downstream. The mean monthly releases have been analyzed to provide a numerically valid reference point for analyzing flows into the lower river for interpretative purposes only. The results of this analysis in terms of estimated flow rates and volumes are as follow:

Discharge Measured for the City of Tampa Dam Releases:	Typical Monthly Values	
	Wet Month	Dry Month
. Mean Monthly Release Rate (cfs)	543	161
. Mean Month Release Volume (acre-ft.)	32,800	9,680

Sulphur Springs discharges to the Hillsborough River and is periodically measured by the USGS. Analysis of the published discharge information for the water years 1976-1979 results in the following typical monthly discharge values:

Sulphur Springs Discharge:	Typical Monthly Values	
	Wet Month	Dry Month
. Mean Monthly Flow Rate (cfs)	38.3	33.2
. Mean Monthly Flow Volume (acre-feet)	2,310	2,000

In like manner, flows were estimated for the Alafia River at the Bell Shoals Road bridge based on USGS measured discharges of the Alafia River near Lithia and Lithia Springs near Lithia, Florida. These flows will be used to analyze the pollutant loads associated with Alafia River entering Hillsborough Bay. The results of this evaluation are as follows:

Discharge of Alafia River Measured at Bell Shoals Road:	Typical Monthly Values	
	Wet Month	Dry Month
. Mean Monthly Flow Rate (cfs)	1,130	461
. Mean Monthly Flow Volume (acre-feet)	68,300	27,800

These hydrologic response values were used for estimation of pollutant loads in the following section and are subsequently compared to river flows. Specific methodology and response values and variations are described in detail in the Appendix in subsections with the same titles.

SECTION 4

URBAN RUNOFF LOADS

Water quality data collected by the USGS during storm events and base flow conditions in 9 urban basins (Tampa Bay Urban Study) was analyzed by the USGS to determine relationships between: (1) recorded physical basin characteristics and meterological factors; and (2) observed storm loads and base flow loads for select pollutants.

As with the hydrologic responses, multiple regression modeling was used to analyze this water quality information. Based on the selected pollutant load data, predictive models generated by the USGS from the regression analysis are displayed in Table 4-1.

These six pollutant load models were applied to each of the thirteen urban basins. Utilizing appropriate physical, cultural and environmental factor values, each day within the two representative months for both wet and dry seasons was evaluated. The individual basin responses to single storms were analyzed and aggregated to the level of the three major drainage basins and the entire Tampa Urban Area.

Base flow water quality information contained within the urban data base was analyzed for mean concentration values for the same six pollutants. These mean values were combined with the predicted base flows from each of the thirteen urban basins to predict base flow pollutant loads.

Suspended solids data were not collected by the USGS in the Tampa Bay Urban Study. Based upon studies conducted in Houston, Texas, a relationship for suspended solids loads based upon storm runoff values was used to evaluate storm loads. Base flow loads were developed from mean suspended solids concentrations in local streams as monitored by the Hillsborough County Environmental Protection Commission.

The cumulative monthly loads for a typical wet and dry month are presented in Tables 4-2, 4-3, 4-4, and 4-5 for the three major drainage areas and the Tampa Urban Area. These tables include the total load as well as the base flow and storm event components for each of the seven selected pollutants.

In addition to urban runoff pollutant loads, the load component attributed to the Hillsborough River entering the reservoir has been evaluated. This evaluation utilized local monthly precipitation, flow and water quality data to establish the following typical wet and dry month loads. Specific methodology and intermediate values used in these analyses are contained in Appendix A.

Loads Calculated at Fowler Avenue Bridge:	Typical Monthly Loads (lbs/month)	
	Wet Month	Dry Month
Pollutant Loads		
. Biochemical Oxygen Demand	127,000	44,700
. Suspended Solids	410,000	161,000
. Total Kjeldahl Nitrogen	16,700	8,820
. Total Nitrogen*	34,800	18,400
. Total Phosphorus	58,800	15,400

*Total Nitrogen estimate based on relationship between TN and TKN developed for Hillsborough River and discussed in Appendix.

TABLE 4-1 : LOAD REGRESSION EQUATIONS FOR SELECT BASINS IN THE TAMPA URBAN AREA

(Standard Form of Equation: $y = a + b_1X_1 + b_2+X_2 + b_3X_3$)

Constituent (Dependent Variable)	Y-Axis Intercept (a)	Independent Variables bi	Independent Variables Xi	Correlation Coefficient (R^2)	Standard Error
BOD	-65.9	+1.92	PQ	0.85	±43.5%
		+15.3	DRY		
		+287.9	ANT_2		
COD	-1130	+17.7	PQ	0.93	±31.7%
		+96.3	DRY		
		+4705	LUDT		
TN	-26.6	+0.50	PQ	0.92	±64.9%
		+5.1	DRY		
		+38.6	TIA		
TON	-22.64	+0.60	PQ	0.78	±35.2%
		+3.8	DRY		
TP	-6.49	+0.16	PQ	0.85	±64.9%
		+39.9	LUNT		
TPb	-0.81	+0.5	PQ	0.87	±52.8%
		+10.6	LUDT		

where:

PQ = peak storm flow (cfs)
DRY = dry days prior to storm (days)
ANT_2 = two-day antecedent precipitation (inches)
TIA = total impervious area (sq.mi.)
LUDT = land use - total developed (sq.mi.)
LUNT = land use - total natural (sq.mi.)

TABLE 4-2 : CUMULATIVE MONTHLY LOADS FOR TYPICAL WET AND DRY MONTHS FOR THE HILLSBOROUGH RIVER RESERVOIR

	Pollutant Loads (lbs./month)		
	Base Flow	Storm Event	Combined
TYPICAL WET MONTH LOADS			
. Biochemical Oxygen Demand	13,100	9,860	23,000
. Chemical Oxygen Demand	137,000	103,000	240,000
. Suspended Solids	47,400	17,200	64,600
. Total Nitrogen	4,040	1,290	5,330
. Total Organic Nitrogen	2,380	123	2,500
. Total Phosphorus	595	1,560	2,160
. Total Lead	247	516	763
TYPICAL DRY MONTH LOADS			
. Biochemical Oxygen Demand	8,020	2,250	10,300
. Chemical Oxygen Demand	83,000	32,000	117,000
. Suspended Solids	29,100	3,880	33,000
. Total Nitrogen	2,480	891	3,370
. Total Organic Nitrogen	1,460	434	1,890
. Total Phosphorus	365	327	692
. Total Lead	152	109	261

TABLE 4-3: CUMULATIVE MONTHLY LOADS FOR TYPICAL WET AND DRY MONTHS FOR THE LOWER HILLSBOROUGH RIVER

	Pollutant Loads (lbs./month)		
	Base Flow	Storm Event	Combined
TYPICAL WET MONTH LOADS			
. Biochemical Oxygen Demand	29,300	15,600	44,900
. Chemical Oxygen Demand	308,000	117,000	425,000
. Suspended Solids	106,000	97,000	203,000
. Total Nitrogen	9,030	2,960	12,000
. Total Organic Nitrogen	5,300	231	5,330
. Total Phosphorus	1,330	1,460	2,790
. Total Lead	552	871	1,420
TYPICAL DRY MONTH LOADS			
. Biochemical Oxygen Demand	17,800	3,710	21,500
. Chemical Oxygen Demand	188,000	43,000	231,000
. Suspended Solids	64,800	22,400	87,200
. Total Nitrogen	5,520	1,640	7,160
. Total Organic Nitrogen	3,250	737	3,990
. Total Phosphorus	811	308	1,120
. Total Lead	338	180	518

TABLE 4-4 : CUMULATIVE MONTHLY LOADS FOR TYPICAL WET AND DRY MONTHS FOR THE DIRECT DISCHARGES TO HILLSBOROUGH BAY

	Pollutant Loads (lbs./month)		
	Base Flow	Storm Event	Combined
TYPICAL WET MONTH LOADS			
. Biochemical Oxygen Demand	27,400	9,720	37,100
. Chemical Oxygen Demand	289,000	402,000	691,000
. Suspended Solids	104,000	41,200	145,000
. Total Nitrogen	8,500	4,100	12,600
. Total Organic Nitrogen	4,980	607	5,590
. Total Phosphorus	1,240	4,580	5,820
. Total Lead	518	1,720	2,240
TYPICAL DRY MONTH LOADS			
. Biochemical Oxygen Demand	20,200	2,140	22,300
. Chemical Oxygen Demand	213,000	93,100	306,000
. Suspended Solids	73,300	9,630	82,900
. Total Nitrogen	6,270	1,350	7,620
. Total Organic Nitrogen	3,680	467	4,150
. Total Phosphorus	917	956	1,870
. Total Lead	382	359	741

TABLE 4- 5 : CUMULATIVE MONTHLY LOADS FOR TYPICAL WET AND DRY MONTHS FOR THE ENTIRE TAMPA URBAN AREA

	Pollutant Loads (lbs./month)		
	Base Flow	Storm Event	Combined
TYPICAL WET MONTH LOADS			
. Biochemical Oxygen Demand	69,700	35,200	105,000
. Chemical Oxygen Demand	735,000	622,000	1,357,000
. Suspended Solids	257,400	155,400	412,000
. Total Nitrogen	21,600	8,350	30,000
. Total Organic Nitrogen	12,700	960	13,700
. Total Phosphorus	3,160	7,600	10,800
. Total Lead	1,320	3,110	4,430
TYPICAL DRY MONTH LOADS			
. Biochemical Oxygen Demand	46,100	8,100	54,200
. Chemical Oxygen Demand	485,000	168,000	654,000
. Suspended Solids	167,000	35,900	203,000
. Total Nitrogen	14,300	3,880	18,200
. Total Organic Nitrogen	8,390	1,640	10,000
. Total Phosphorus	2,100	1,590	3,690
. Total Lead	871	648	1,520

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Similarly, water quality data collected immediately downstream of the dam was combined with mean monthly dam releases to calculate representative wet and dry month loads entering the lower river from the reservoir. These loads are developed for interpretative purposes for the following section of the report.

The estimated monthly loads for wet and dry months are as follows:

Loads Calculated for City of Tampa Dam Releases:	Typical Monthly Loads (lbs)	
	Wet Month	Dry Month
Pollutant Loads		
. Biochemical Oxygen Demand	143,000	36,700
. Suspended Solids	851,000	130,000
. Total Kjeldahl Nitrogen	18,500	5,630
. Total Nitrogen*	38,500	11,700
. Total Phosphorus	44,400	10,000

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*Based on relationship between TN and TKN developed for the Hillsborough River.

Specific intermediate pollutant load values and methods used in this analysis are contained in the Appendix of this report. Interpretation of these load values is contained in the following section.

Comparison of the mean monthly flow and pollutant load values for the Hillsborough River at Fowler Avenue and the Dam releases reveals discontinuities for both wet and dry months. This is caused by several factors which include: (1) change in storage in the reservoir; (2) withdrawals from the reservoir by the City of Tampa for water supply purposes; (3) nutrient assimilation and release by the faunal communities residing in the reservoir; (4) presence of septic tanks along the reservoir banks; (5) evaporative losses and groundwater recharge; (6) natural sedimentation and resuspension processes in the reservoir; and, (7) algal wash out. These factors, either singularly or in combination, can cause significant variations in reservoir water quality which impacts the predicted flows and pollutant loads estimated for dam releases to the lower river.

Discharge from Sulphur Springs to the Lower Hillsborough River was evaluated for pollutant loads. No data was available for BOD, SS, TN or TP. For lack of data, BOD = SS = 0 which is generally true for groundwater. Monthly loads for TN and TP were based on USGS measured discharge and observed concentrations in the closest wells in the same geologic unit. Estimated loads are as follows:

	Typical Monthly Loads	
Estimated Loads for Sulphur Springs:	Wet Month	Dry Month
. Total Nitrogen (lbs./mo.)	501	434
. Total Phosphorus (lbs./mo.)	344	299

The load component attributed to the Alafia River entering Hillsborough Bay has also been evaluated. This evaluation utilized local monthly precipitation, flow and water quality data to establish the following typical wet and dry month loads. Specific methodology used in these analyses are contained in Appendix A.

	Typical Monthly Loads (lbs/month)	
Loads Calculated at Bell Shoals Bridge:	Wet Month	Dry Month
Pollutant Loads		
. Biochemical Oxygen Demand	279,000	116,000
. Suspended Solids	1,396,000	697,000
. Total Kjeldahl Nitrogen	164,000	38,600
. Total Nitrogen*	395,000	92,800
. Total Phosphorus	663,000	239,000

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*Total Nitrogen estimate based on the relationship between TN and TKN developed for the Alafia River and discussed in Appendix.

SECTION 5

INTERPRETATIONS AND OBSERVATIONS

Hydrologic and pollution load responses to given precipitation events, utilizing a variety of predictive methods, have been prepared and analyzed in the two preceeding sections of this report. This section will discuss the generated typical wet and dry month values for flow and selected pollutant loads. Tables 5-1 and 5-2 contain the typical monthly loads for cumulative monthly flows and selected pollutant loads for the wet and dry seasons with values for each drainage area and the total area. The individual loads have been compared to the total load, in the form of percent of total load, in Table 5-1 whereas Table 5-2 evaluates the specific yield, in terms of parameter value per acre, for each individual load. Table 5-3 summarizes the mean concentration for each pollutant (total load divided by total volume).

Reservoir Segment

This segment receives inflow from the Hillsborough River and four urban basins. Flow leaves this segment when released at the dam into the lower river segment or withdrawn slightly upstream at the City water treatment plant intake. Additionally, the reservoir has a fixed storage capacity which is monitored to provide water supply and control downstream releases. This aspect of the segment explains the discontinuity in flow volumes and pollutant loads entering the lower river.

As shown in Table 5-1, the relative component of the Total Urban Area Non-Point load is generally less than 20% with slightly higher relative values occurring during the wet months. With regard to specific yields shown in Table 5-2, the responses for the reservoir segment tend to be within ± 10% of the mean specific yields for the entire urban area except for BOD (+14%) and SS (-19%) during the wet months and V (-49%) during the dry season. Mean monthly concentrations, as shown in Table 5-3 tend to be within ±10% of the mean concentration values for the entire urban

TABLE 5-1: MONTHLY LOADS AND RELATIVE CONTRIBUTIONS OF SELECTED POLLUTANTS FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA FOR TYPICAL WET AND DRY MONTHS

	TYPICAL MONTHLY LOADS						Total Urban Area
	Reservoir		Lower River		Bay Discharge		Non-Poin
	Load	% Total	Load	% Total	Load	% Total	Load
Wet Months							
. V	908	18	2,150	43	1,920	39	4,980
. BOD	23,000	22	44,900	43	37,100	35	105,000
. SS	64,500	16	203,000	49	145,000	35	413,000
. TN	5,330	18	12,000	40	12,600	42	29,900
. TP	2,160	20	2,790	26	5,820	54	10,800
Dry Months							
. V	545	16	1,240	35	1,730	49	3,520
. BOD	10,300	19	21,500	40	22,300	41	54,100
. SS	33,000	16	87,200	43	82,900	41	203,000
. TN	3,370	19	7,160	39	7,620	42	18,20
. TP	692	19	1,130	30	1,870	51	3,680

Note: All values in pounds except Volume which is in acre-feet.

TABLE 5-2: MONTHLY LOADS AND SPECIFIC YIELDS OF SELECTED POLLUTANTS FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA FOR TYPICAL WET AND DRY MONTHS

	TYPICAL MONTHLY LOADS AND SPECIFIC YIELDS							
	Reservoir (8,017 Acres)		Lower River (16,898 Acres)		Bay Discharge (16,753 Acres)		Total Urban Area (41,688 Acres)	
	Load	Yield	Load	Yield	Load	Yield	Load	Yield
Wet Months								
. V	908	0.113	2,150	0.127	1,920	0.115	4,980	0.120
. BOD	23,000	2.87	44,900	2.66	37,100	2.21	105,000	2.52
. SS	64,500	8.05	203,000	12.01	145,000	8.66	413,000	9.91
. TN	5,330	0.66	12,000	0.71	12,600	0.75	29,900	0.72
. TP	2,160	0.27	2,790	0.17	5,820	0.35	10,800	0.26
Dry Months								
. V	345	0.043	1,240	0.074	1,730	0.103	3,520	0.084
. BOD	10,300	1.28	21,500	1.27	22,300	1.33	54,100	1.30
. SS	35,000	4.37	87,200	5.16	82,900	4.95	203,000	4.87
. TN	3,370	0.42	7,160	0.42	7,620	0.45	18,200	0.44
. TP	692	0.09	1,120	0.07	1,870	0.11	3,680	0.09

Notes: 1. All loads in pounds except Volume which is in acre-feet.
2. All yields in pounds/acre except Volume which is in acre-feet/acre.

TABLE 5-3: MEAN MONTHLY CONCENTRATIONS OF SELECTED POLLUTANTS FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA FOR TYPICAL WET AND DRY MONTHS

	TYPICAL WET AND DRY MONTH MEAN CONCENTRATIONS			
	Reservoir	Lower River	Bay Discharges	Total Urban Area
Wet Months				
. BOD	9.32	7.69	7.11	7.76
. SS	26.14	34.75	27.79	30.52
. TN	2.16	2.05	2.41	2.21
. TP	0.88	0.48	1.12	0.80
Dry Months				
. BOD	10.99	6.38	4.74	5.66
. SS	37.33	25.88	17.63	21.22
. TN	3.59	2.12	1.62	1.90
. TP	0.74	0.33	0.40	0.38

Note: All values are mg/l.

area except for BOD (+20%) and SS (-14%) during the wet months. These concentration deviations are consistent with the specific yield variations for the wet season. The lower specific yield in runoff volume results in all of the pollutant concentration being substantially higher than +10% with BOD (+94), SS (+76%), TN (+89%) and TP (+95%) having an average deviation from the urban area mean concentrations of +88.5%. While this number does not have precise meaning, it does give a feeling for the overall variance from the urban area mean concentration values that resulted from a dry month specific yield that was below the area mean.

Lower River Segment

The lower river segment receives inflow from the regulated dam releases, discharge from Sulphur Springs, and six urban basins. Flow is attenuated only by minimal in-reach storage and tidal stage in the river prior to discharge to Hillsborough Bay. The discontinuity caused by the dam and reservoir resulted in estimated dam release volumes for wet and dry months.

Table 5-1 shows that the Lower River segment receives 26%-49% of each of the components the entire urban load with an average relative load component of 39%. This basin has approximately twice the area of the reservoir basin and approximately the same area as the direct bay discharge basin. The specific yields, as shown in Table 5-2 tend to fall within ±10% of the mean values of the entire urban area with the exception of SS (+21%) and TP (-35%) during the wet season and V (-12%) and TP (-22%) during the dry season.

Evaluation of the mean monthly runoff concentrations, as shown in Table 5-3, shows that the variations seen in specific yield in the wet season are also reflected in the deviations of SS (+14%) and TP (-40%) during the wet months. However, as seen in the reservoir, the deviation in specific yield for volume during the dry season has significant impacts on mean concentration variations for the dry months. BOD (+13%), SS (+22%) and TN (+12%) tend to be slightly higher in mean concentration while TP (-13%) is somewhat lower due to the -12% variation in specific volumetric yield.

Bay Segment

This segment receives urban runoff directly from three large urban basins and indirectly from the discharge of the Hillsborough River. Palm River and Delaney Creek discharge to Hillsborough Bay and act as conduits that convey the urban runoff to the bay. The Alafia River and Bullfrog Creek also discharge to Hillsborough but do not have an urban runoff component.

The relative urban runoff component, as shown in Table 5-1, ranges from 35% to 51% with an average value of 43.9%--the larges of the three major drainage areas. Half of the Hillsborough Bay Basin specific yields, as shown in Table 5-2, are within ±10% of the mean values for the entire urban area. The more variant specific yield values are for BOD (-12%), SS (-13%) and TP (+35%) for the wet season and V (+23%) and TP (+22%) for the dry season. The mean monthly concentrations for the bay discharge segment reflect the specific yield variations with only the TP (+40%) significantly deviant during the wet months and BOD (-16%), SS (-17%) and TN (-15%) deviant beyond -10% of the mean values for the entire urban area. Again, the higher dry season specific volume yield of +23% resulted in pronounced impact in the lowered monthly mean concentrations for all pollutants except TP.

Comparison to Field Data

Ideally, these estimated pollutant loads would be compared to load estimates based on field samples. However, no agency has undertaken the systematic collection of urban runoff data from these basins and analyzed the data to develop or project pollutant loads. Urban runoff data, collected by the USGS, in the Tampa Bay Region, was analyzed and used to prepare the load regression models which were employed in these wet and dry month pollutant load estimates. Unfortunately, the USGS data can not be used directly to evaluate the accuracy of these estimates.

APPENDIX A

METHODOLOGY

Introduction

The contents of this appendix include the assumptions and methodology utilized to arrive at various intermediate and final values, including many of the values. Each section addresses a single aspect of the analysis and explains the basic assumptions, theory, and procedural steps utilized.

Precipitation

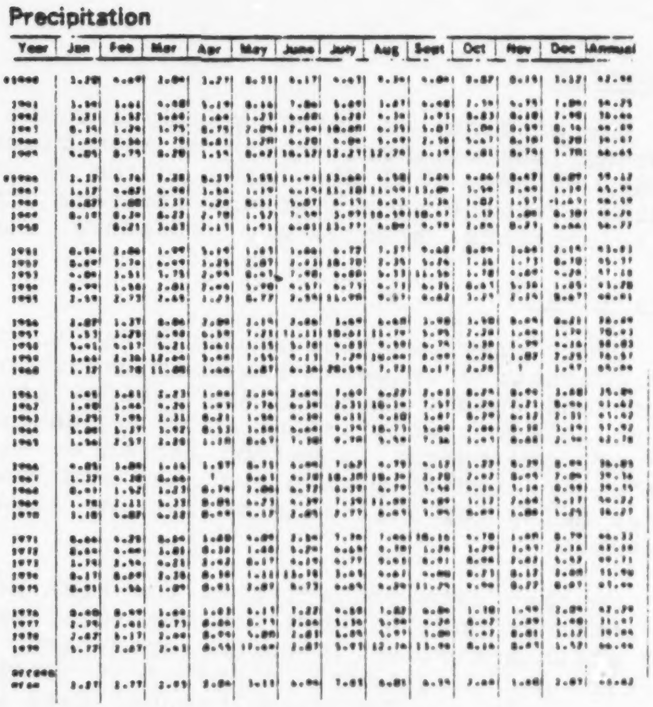
Since precipitation is essential to this study, selection of representative values for use in determining urban precipitation and runoff quantity and quality is very critical. In order to select precipitation event sequences which are typical of wet and dry months, a method had to be selected which accurately represented probable annual and monthly rainfall totals while allowing for realistic variations between individual rainfall events.

Weather data collected at the NOAA weather station at Tampa International Airport has been utilized. The period of record at this station is sufficiently long to indicate both short-term and long-term variations in monthly and annual precipitation values. Individual annual data were analyzed to determine which years most closely approximate the long-term annual rainfall value of 48.82 inches. Table A-1 displays the published monthly totals, the monthly mean values, and the annual mean values for each year from 1940 through 1979.

Based upon analyzing the monthly and annual variations, five years which have rainfall totals closest to the long-term mean annual value were selected for further consideration. The result and analysis identifying annual precipitation deviations is that the years 1949, 1955 and 1973 are all within ±2 percent of the mean annual rainfall (Table A-2). Therefore, these years were selected as representative of the long-term precipitation in Tampa and used for subsequent analyses.

Determination of typical wet and dry months was based upon analyzing the wet and dry months which occurred during the representative three years. Table A-3 contains the monthly precipitation totals for the three representative years, designates the wet months, and displays typical characteristics for the wet and dry months.

TABLE A-1: MONTHLY PRECIPITATION DATA FOR TAMPA, 1940-1979



Precipitation

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual

TABLE A-2: PRECIPITATION DEVIATION SUMMARY

Year	Precipitation (in)	Precipitation Difference from Mean Annual Value (in)	(%)
1952	45.37	-3.45	-7.07
1971	46.33	-2.49	-5.10
1948	46.59	-2.23	-4.57
1949	48.24	-0.58	-1.19
1955	48.81	-0.01	-0.02
Average	48.82	-0-	-0-
1973	49.71	0.89	1.82
1969	54.22	5.40	11.06
1941	54.25	5.43	11.12
1950	56.22	7.40	15.16
1953	57.18	8.36	17.12

Reproduced from best available copy.

TABLE A-3: MONTHLY PRECIPITATION VALUES FOR 1949, 1955, and 1975 WET SEASON AND DRY SEASON CHARACTERISTICS

	Monthly Precipitation (inches)			
Month	1949	1955	1973	Monthly Average
January	0.18	2.59	3.75	2.17
February	0.34	2.73	2.54	1.87
March	0.22	2.65	4.21	2.36
April	2.70	1.23	2.42	2.12
May	1.52	0.72	0.17	0.80
June	7.59*	2.55	4.19*	4.78
July	3.79	11.90*	4.77*	6.82
August	18.59*	9.57*	9.43*	12.53
September	10.47*	8.82*	8.91	9.40
October	1.32	3.23	0.98	1.84
November	1.04	2.15	2.82	2.00
December	0.30	0.67	5.52*	2.16
Annual Total	48.24	48.81	49.71	48.92

*Designates wet month.

Net Months:	1949	1955	1973	3 Year Total
Number	3	3	5	11
Total Precipitation	36.65	30.29	3282	99.76
Percent of Annual Total	76%	62%	66%	68%
Monthly Minimum	5.59	8.82	4.19	4.19
Monthly Mean	12.22	10.10	6.56	9.07
Monthly Maximum	18.59	11.90	9.43	18.59
Dry Months:				
Number	9	9	7	125
Total Precipitation	11.59	18.52	16.89	47.00
Percent of Annual Total	24%	38%	34%	32%
Monthly Minimum				
Monthly Mean	1.29	2.06	2.41	1.88
Monthly Maximum				

Detailed examination of the precipitation event sequences, monthly amounts, and monthly means for the eleven wet months and twenty-five day months led to selecting June, 1949, and September, 1955, as typical wet months with May, 1949, and November, 1955, identified as typical dry months. The fact that a month in 1973 was not chosen as typical of either wet or dry season was only coincidental. Actual daily precipitation values for each of the four selected months are presented in Table A-4.

Utilizing actual precipitation event sequences for representative wet and dry months define urban runoff quantity and quality responses is more representative of real world precipitation event quantities, distribution, and antecedent conditions than either historical probabilistic values or long-term daily average values. Additionally, actual values will more clearly define the range and variability in precipitation values and the resultant quantity and quality responses of the individual urban basins. Table A-5 summarizes the precipitation characteristics for the two representative months for both the wet and dry seasons.

TABLE A-4: PRECIPITATION AMOUNT AND DISTRIBUTION FOR TYPICAL WET AND DRY MONTHS

	Wet Months		Dry Months	
	June 1949	September 1955	May 1949	November 1955
1	1.15	0.143	T	0
2	0	1.80	0	0
3	0	0.09	0.03	T
4	0	1.00	T	T
5	0	0.18	0	0
6	0	T	0	0
7	0	0.11	0	0
8	0.14	0.29	0.06	0
9	0.08	T	0	0.69
10	0.04	1.45	0	1.31
11	0.35	0.09	1.04	0
12	0.47	0.23	T	0
13	T	T	T	0
14	0.80	0	0	0
15	T	T	0	0
16	T	0	0	0
17	0.02	T	0	0
18	1.31	0.04	0	0
19	1.28	0	0	0
20	0.13	1.20	0	0
21	T	0	0	0
22	0.87	0.22	0	0
23	0.09	0.07	0	0
24	0.01	0	0	0
25	T	0.55	0	0
26	0.49	0.35	0	
27	0	0	0	0.15
28	0	0.12	0	T
29	0.36	0	0	T
30	T	0	0	0
31			0.39	
Total	7.59	8.82	1.52	2.15

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TABLE A-5: PRECIPITATION AND ANTECEDENT CONDITIONS FOR TYPICAL WET AND DRY MONTHS

	Wet Month1)	Dry Month1)
Rainfall		
. All events (excluding trace amounts		
- Average Number of Events	16.5	3.5
- Event Amount	0.01 0.50 1.80	0.03 0.52 1.31
. Storm Events ($P \geq 0.10$ inch)		
- Average Number of Events	12.0	2.5
- Event Amount	0.11 0.55 1.80	0.15 0.72 1.31
Antecedent Conditions2)		
. Dry Days ($P < 0.10$ inch)	0 1.9 8	0 14.8 27
. 1-Day Condition	0.00 0.29 1.46	0.00 0.14 0.69
. 2-Day Condition	0.00 0.77 3.79	0.00 0.14 0.69
. 14-Day Condition	0.39 4.42 9.05	0.00 1.00 2.98

1) Triad values represent minimum, mean, and maximum values.

2) Antecendent conditions have been calculated for storm events only.

Urban Basin Analysis

Urban runoff basins were delineated in such a manner that the individual basins could be aggregated to evaluate urban runoff volumes and loads to the Hillsborough River Reservoir (Fowler Avenue to the Dam), the Lower Hillsborough River (Dam to Mouth), and directly to Hillsborough Bay. Through dividing the study area into thirteen basins, were defined which allowed reasonable accuracy in developing urban runoff estimates while still being manageable in terms of the total number of calculations required to arrive at preliminary runoff flows and pollutant loads.

Basin delineation was accomplished through using the City of Tampa Drainage Atlas and the most current USGS quadrangle maps. The portions of the urban basins which are within the City limits were separated through reviewing existing storm sewer systems locations, drainage directions, sub-catchment interconnections, and land surface elevations. The majority of the total basin area (81 percent) fell within the City limits.

Many of the basins extended beyond the City limits into Hillsborough County. For these areas, basin boundaries were defined utilizing USGS quadrangle maps, aerial photos, and field inspections. Generally, the degree of accuracy for drainage basin delineation beyond the City limits is lower.

Land use evaluations were accomplished utilizing 1976 land use summaries for the thirteen individual subsectors comprising Planning Sectors A and B as published by the Hillsborough County Planning Commission in 1976, and the current Phase I land use plans for the same subsectors as published by the City of Tampa in its' Comprehensive Plan 2000. Through overlaying land use classifications upon drainage area boundaries, subsector land use information was converted into basin land use summaries.

The numerous specific types of land use contained in the 1976 thirteen subsector summaries and the Phase I land use plan were reduced to three general classes of land use. These classes include Developed, Residential, and Natural with the numerous types of specific land uses allocated to the three land use classes according to the matrix identified in Table A-6.

TABLE A-6: LAND USE CLASSIFICATION MATRIX

Specific Land Use[1]	Land Use Class Developed	 Residential	 Natural
1. Residential - Low Intensity		X	
2. Residential - Low to Medium Intensity		X	
3. Residential - Medium Intensity		X	
4. Residential - High Intensity		X	
5. Commercial - Community	X		
6. Commercial - Highway	X		
7. Commercial - Existing (Requiring more Study)	X		
8. Commercial - Planned		X	
9. Transportation and Road Network	X		
10. Transportation	X		
11. Communication	X		
12. Utilities	X		
13. Urban Core	X		
14. Industrial/Manufacturing - Heavy	X		
15. Industrial/Manufacturing - Light	X		
16. Industrial/Manufacturing - Planned			X
17. Public/Semi-Public	X		
18. Recreation			X
19. Open			X
20. Undeveloped			X
21. Preservation			X
22. Agricultural			X

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[1] Subsector Identifying Hillsborough County Planning Commission, 1976.

Basin characteristics including size, land use and receiving waters are summarized in Table A-7 for each of the thirteen urban basins and the Tampa Urban Area. The predominent land use in each of the three major drainage areas and twelve of the thirteen individual basins was residential. The single exception is basin HB-B which includes the majority of the port facilities, terminals and materials storage areas along the eastern shore of Hillsborough Bay. On balance, residential land uses account for approximately 60 percent of the 65 square mile Tampa Urban Area, while developed and natural land uses nearly split the remaining 40 percent. The six basins which drain to Lower Hillsborough River significantly deviate from this trend and average 80.9 percent residential land use.

The boundary of the Tampa Urban Area utilized for this investigation extends beyond the boundary of the City Limits to include approximately 8,083 acres or 12.63 square miles of Hillsborough County. Some areas of the City, notably the western two-thirds of the Interbay Penninsula and portions of western and northwestern Tampa (amounting to 22,072 acres or 24.48 square miles) are not included within the study area since they drain to Old Tampa Bay.

Regional Urban Runoff Data

As described in Section 2, Pertinent Local Studies and Data, limited water quality data has been collected under programs designed for analyzing urban runoff impacts. The principal exception is the data that has been collected for nine urban basins within the Tampa Bay Area by the USGS under its urban studies program since 1975.

The USGS effort has managed to collect fairly complete information on the hydraulic/hydrologic response of 201 identifiable storms while consistent and complete water quality information was obtained for 21 identifiable storms in the nine urban basins. This information is available for retrieval through the USGS computer data system, WATSTOR, and portions of the data have been published in WRI 78-125, *Hydrologic Data from Urban Watersheds in the Tampa Bay Area, Florida*. Quantity and quality information obtained under this program has been extensively used in this subsequent analyses.

TABLE A-7: BASIN SIZE AND LAND USE CHARACTERISTICS

	Drainage Area Size		Land Use						
			Developed		Residential		Natural		
Basin	Acres	Sq.Miles	Acres	Percent	Acres	Percent	Acres	Percent	Receiving Waters
R-1	1600	2.50	85	5.3	967	60.4	548	34.3	Reservoir
R-2	1545	2.41	48	3.1	480	31.1	1017	65.8	Reservoir
R-3	3268	5.11	1214	37.1	1842	56.4	212	6.5	Reservoir
R-4	1604	2.51	32	2.0	1300	81.0	272	17.0	Reservoir
Reservoir Basin	8017	12.53	1379	17.2	4589	57.2	2049	25.6	
L-1	2880	4.50	239	8.3	2481	86.1	160	5.6	Lower River
L-2	1550	2.42	240	15.5	876	56.5	434	28.0	Lower River
L-3	3366	5.26	63	1.9	2953	87.7	350	10.4	Lower River
L-4	3540	5.53	400	11.3	2931	82.8	209	5.9	Lower River
L-5	3978	6.22	732	18.4	3082	77.5	164	4.1	Lower River
L-6	1584	2.48	31	2.0	1350	85.2	203	12.8	Lower River
Lower Rvr. Basins	16,898	26.40	1,705	10.1	13,673	80.9	1,520	9.0	

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TABLE A-7: BASIN SIZE AND LAND USE CHARACTERISTICS (cont'd)

Basin	Drainage Area Size		Land Use						Receiving Waters
			Developed		Residential		Natural		
	Acres	Sq.Miles	Acres	Percent	Acres	Percent	Acres	Percent	
HB-P	4402	6.88	320	7.3	3590	81.6	492	11.1	Hillsborough Bay
HB-I	3176	4.96	538	16.9	908	28.6	1730	54.5	Hillsborough Bay
HB-B	9175	14.34	3755	40.9	2560	27.9	2860	31.2	Hillsborough Bay
Hillsborough Bay Basins	16,753	26.18	4,613	27.5	7,058	42.1	5,082	30.3	
Tampa Urban Area	41,668	65.11	7,697	18.5	25,320	60.8	8,651	20.8	

Hydrologic Response Analysis

The regional urban runoff data from 201 identifiable storms has been collected and analyzed by the USGS to derive a method for predicting the hydrologic response of an urban basin knowing only specific physical characteristics and pertinent precipitation data. In the USGS study, the multiple-linear-regression technique was used to define spatial variations in runoff quantity characteristics as a function of the physical and climatic aspects of the urban basins. The general form of a multiple-linear regression is

$$Y = a + b_1 X_1 + b_2 X_2 + \dots b_n X_n$$

where Y is a water-quantity characteristic (dependent variable), the X's are basin characteristics (independent variables), a is the regression constant, the b's are regression coefficients, and n is the number of basin characteristics. Nonlinear relationships between hydrologic variables have frequently been found to be linear if the variables are transformed to logarithms. The general form of a log-transform regression is

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + \dots b_n \log X_n$$

An equivalent form of this equation is

$$Y = a X_1^{b_1} X_2^{b_2} \dots X_n^{b_n}$$

Because the logarithm of zero is undefined, a constant, such as 1.0, is added to all independent variables that could feasibly be zero. Both forms of the regression equations were tested; however, the log-transform regressions were found to fit the existing runoff quantity values better than the linear form.

SAS 76, a statistical analysis system developed at North Carolina State University was used to perform stepwise multiple regression and associated calculations. The SAS 76 stepwise regression procedure was used in the analysis of the response matrices for the nine study basins. This procedure examines the contribution made by each variable at every step. A variable once a part of the regression may exit later due to its relationship with remaining variables in the regression.

The following goals were established by the USGS for regression models:

- Multiple correlation coefficient greater than 0.8.
- Standard error of estimate <50 percent.
- Selection of regression model with highest correlation coefficient.

Three specific hydrologic response variables were sought through this analysis: 1) baseflow response for days without storm events; 2) peak runoff value for storm events; and 3) runoff volume for days with storm events (baseflow and storm event runoff). Physical characteristics included drainage area, channel slope, soils index, percent of area in standing water, total impervious area and effective impervious area, as well as precipitation factors including total storm rainfall, dry days prior to the storm, and the antecedent 1, 2, 7 and 14 day conditions were used as independent variables.

Based on 201 storms in the nine urban basins, the following preliminary predictive modesl emerged from the USGS regression analysis:

Base Flow Model

$$BF = 0.37\ (DA)^{1.18}\ (TRF+1)^{2.73}\ (ANT_{14}+1)^{0.55}\ \text{cfs}$$

$r = 0.91$

Standard Error = ± 68%

Peak Flow Model

$$PQ = 14.45\ (DA)^{0.57}\ (EIA)^{0.61}\ (TRF)^{0.75}\ (ANT_2+1)^{0.20}\ \text{cfs}$$

$r = 0.83$

Standard Error = ± 52%

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Runoff Volume Model

$RV = 1.32\,(DA)^{1.14}\,(EIA)^{0.71}\,(TRF)^{1.13}\,(ANT_1+1)^{0.19}$ acre-feet

$r = 0.96$

Standard Error = ± 36%

where DA	=	Drainage Area	(sq.mi.)
TRF	=	Total Storm Rainfall	(in.)
EIA	=	Effective Impervious Area	(sq.mi.)
ANT_1	=	Antecedent 1-Day Precipitation	(in.)
ANT_2	=	Antecedent 2-Day Precipitation	(in.)

For the purpose of the following analyses, storm events are those events having precipitation greater than or equal to 0.10 inch. Days with less than 0.10 inch of precipitation are regarded as dry days since previous investigations have shown that 0.10 inch or more is required to cause significant runoff in urban basins.

Effective impervious area, the single physical characteristic which can not be directly measured from available mapping, was derived by the USGS from information on the nine urban basins. Several different types of impervious areas were determined for the USGS urban basins and is summarized as follows:

Watershed Number	Area (sq.mi)	Total Impervious Area (%)	Hydraulicly Connected Impervious Area (%)	Effective Impervious Area (%)	Composite C-Value (%)
1	0.34	61	53	37	55
2	1.40	19	5.5	5.5	30
3	0.51	27	9.0	9.0	35
4	1.29	38	28	20	37
5	1.79	36	26	20	37
6	3.45	41	26	18	44
7	1.89	32	25	25	37
8	1.72	38	26	26	43
9	0.45	48	33	20	56

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In addition to the various measured imperviousness values, the compostie C-value shown for each basin represents the weighted result of runoff coefficients for both developed and residential land uses. Analysis of this composit value in comparison to the total impervious area reveals a statistical relationship. The total impervious area also shares a statistical relationship with the effective impervious area. Procedurally, for each basin,

$$\text{COMP} = 0.85\ (\%\ \text{Developed Area}) + 0.32\ (\%\ \text{Residential Area})$$

Estimate the percent total impervious area by

$$\%\ \text{TIA} = -13.76 + 124.1\ (\text{COMP}) \quad \text{where} \quad \begin{aligned} n &= 9 \\ r &= 0.92 \\ SE &= \pm\ 0.1\% \end{aligned}$$

Estimate the percent effective impervious area by

$$\%\ \text{EIA} = 0.07\ (\%\ \text{TIA})^{1.54} \quad \text{where} \quad \begin{aligned} n &= 9 \\ r &= 0.88 \\ SE &= \pm\ 29\% \end{aligned}$$

Finally, calculate EIA by

$$\text{EIA} = \text{DA} \times (\%\ \text{EIA})$$

where DA is the drainage area in appropriate units.

It is very important to note that these models and relationships are preliminary in nature and may change slightly in the published USGS water resource investigation report which is expected to be available in the form of cooperator draft in January 1981.

This procedure was applied to each of the thirteen urban basins identified for the present investigation with the following results:

			Estimated Values			
Basin	Drainage Area (sq.mile)	Composite C-Value (%)	Total Impervious Area (%)	Total Impervious Area (sq.mi.)	Effective Impervious Area (%)	Effective Impervious Area (sq.mi.)
R-1	2.50	23.8	15.8	0.40	4.9	0.12
R-2	2.41	12.6	19.0	0.46	2.0	0.05
R-3	5.11	49.6	47.8	2.44	27.0	1.38
R-4	2.51	27.6	20.5	0.51	7.3	0.18
L-1	4.50	34.6	29.2	1.31	12.6	0.57
L-2	2.42	31.3	25.1	0.61	10.0	0.24
L-3	5.26	29.7	23.1	1.22	8.8	0.46
L-4	5.53	36.1	31.0	1.71	13.9	0.77
L-5	6.22	40.4	36.4	2.26	17.7	1.10
L-6	2.48	29.0	22.2	0.55	8.3	0.21
HB-P	6.88	32.3	26.3	1.81	10.8	0.74
HB-I	4.96	23.5	15.4	0.76	4.7	0.23
HB-B	14.34	43.7	40.5	5.81	20.9	3.00
Tampa Urban Area	65.11	-	30.5	19.85	13.9	9.05

These hydraulic response models, physcial basin characteristics, precipitation factors, and estimated effective imperviousness values were applied and analyzed for each of the thirteen basins for each day fo the two representative months for both the wet and dry seasons. The individual basin responses were analyzed and aggregated to major drainage level (reservoir, lower river and bay). The analysis of the hydrologic responses for the three dependent variables are contained in Table A-8.

TABLE A-8: TYPICAL WET AND DRY SEASON HYDROLOGIC RESPONSES FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA

	Wet Month	Dry Month
Directly to Hillsborough River Reservoir:		
Base Flow (cfs)	9.6	5.7
	14.5	8.9
	34.8	18.0
Peak Flow (cfs)	12.0	14.7
	46.7	47.3
	117.1	82.9
Runoff Volume (acre-ft)	0.34	0.48
	2.80	3.03
	8.60	4.32
Directly to Lower Hillsborough River:		
Base Flow (cfs)	21.6	12.9
	32.4	19.8
	35.3	31.4
Peak Flow (cfs)	28.2	34.4
	109.4	110.5
	274.3	194.1
Runoff Volume (acre-ft)	1.93	2.77
	15.97	17.30
	49.08	35.38
Directly to Hillsborough Bay:		
Base Flow (cfs)	24.4	14.6
	30.4	28.4
	65.5	35.5
Peak Flow (cfs)	35.5	43.3
	137.9	139.6
	345.4	244.5
Runoff Volume (acre-ft)	0.86	1.20
	6.70	7.53
	21.38	15.39

Note: Values given are minimum, mean and maximum values from the two-month sample periods.

Pollutant Load Response Analysis

The multiple-regression approach provides a means of estimating water quality characteristics for ungaged basins and of estimating the general effects of natural and cultural aspects of drainage basins on water quality. The principal advantage of this approach is that a multiple-regression model can be developed on the basis of available data and can be applied to ungaged basins for which certain physical, cultural, and environmental factors are known.

As previously discussed, the USGS used the SAS 76 statistical system to perform stepwise multiple regressions and associated calculations on stormwater quality data collected by the USGS for twenty-one district storm events. Both the linear and log transorm forms of regression equations were tried in order to derive the best pollutant load models. As opposed to the case of the hydrologic response models which utilized the log transform regression equation, the linear form provided the best fit for observed storm pollution loads. The object of the iterative process involved with the multiple variable regression analysis was to select the load model for each pollutant which had the best multiple correlation value while having reasonable standard errors.

Six specific pollutant models were developed from the USGS Tampa Bay Area urban study data. These include:

- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Total Nitrogen (TN)
- Total Organic Nitrogen (TON)
- Total Phosphorus (TP)
- Total Lead (TPb)

These dependent variables were analyzed against the following physical, cultural and environmental independent variables for the individual basins:

- Drainage Area
- Total Impervious Area
- Effective Impervious Area
- Total Residential Area
- Total Developed Area

- Total Natural Area
- One-day Antecedent Precipitation Condition
- Two-day Antecedent Precipitation Condition
- Seven-day Antecedent Precipitation Condition
- Fourteen-day Antecedent Precipitation Condition
- Total Storm Rainfall
- Maximum Five-Minute Rainfall Intensity
- Maximum Fifteen-Minute Rainfall Intensity
- Maximum One Hour Rainfall Intensity
- Average Storm Rainfall Intensity
- Number of dry days ($P < 0.1$ inch) prior to storm
- Total Storm Runoff Volume
- Peak Storm Discharge

Based on the selected pollutant load data, the following predictive models emerged from the USGS regression analysis:

Biochemical Oxygen Demand Model

$BOD = (-65.9) + (1.92\ PQ) + (15.3\ DRY) + (287.9\ ANT_2)$ lbs.

$r = 0.92$

Standard Error = ± 44%

Chemical Oxygen Demand Model

$COD = (-1130) + (17.7\ PQ) + (96.3\ DRY) + (4705\ LUDT)$ lbs.

$r = 0.96$

Standard Error = ± 32%

Total Nitrogen Model

$TN = (-26.6) + (0.50\ PQ) + (5.1\ DRY) + (38.6\ TIA)$ lbs.

$r = 0.96$

Standard Error = ± 65%

Total Organic Nitrogen Model

$TON = (-22.64) + (0.60\ PQ) + (3.8\ DRY)$ lbs.

$r = 0.88$

Standard Error = ± 35%

Total Phosphorus Model

$TP = (-6.49) + (0.16\ PQ) + (39.9\ LUNT)$ lbs.

$r = 0.92$

Standard Error = ± 65%

Total Lead Model

$TPb = (-0.81) + (0.5\ PQ) + (10.6\ LUDT)$ lbs.

$r = 0.93$

Standard Error = 53%

where:

PQ = Peak Storm Flow (cfs)
DRY = Dry Days prior to Storm (days)
ANT_2 = Two-Day Antecedent Precipitation (inches)
TIA = Total Impervious Area (sq. mi.)
LUDT = Land Use - Total Developed (sq. mi.)
LUNT = Land Use - Total Natural (sq. mi.)

These six pollutant load models were applied to each of the thirteen urban basins utilizing appropriate physical, cultural and environmental factors. Through applying the precipitation event occurences for the two dry and two wet months, individual storm event loads were generated for each basin. The individual basin responses to single storms were then aggregated to the level of the three major drainage basins and the entire Tampa Urban Area. The results of these evaluations are presented in Tables A-9, A-10, A-11, and A-12. The cumulative load for each of the six pollutants has been calculated for each of the three major drainage areas and the entire Tampa Urban Area. Values presented in Table A-13 reflect the total storm load generated during both a typical dry and wet month from three drainage areas and the entire study area.

TABLE A-9: TYPICAL WET AND DRY SEASON SINGLE STORM LOAD RESPONSES FOR THE HILLSBOROUGH RIVER RESERVOIR

	Storm Load (lbs./storm)	
	Net Month	Dry Month
. Biochemical Oxygen Demand	0	484
	822	899
	4,170	1,490
. Chemical Oxygen Demand	8,010	887
	8,610	12,800
	9,950	17,100
. Total Nitrogen	73.8	97.9
	108	356
	223	607
. Total Organic Nitrogen	0	13.7
	10.3	174
	73.3	357
. Total Phosphorus	109	111
	130	131
	173	152
. Total Lead	25.6	27.0
	43.0	43.2
	78.2	61.0

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-10: TYPICAL WET AND DRY SEASON SINGLE STORM LOAD RESPONSES FOR THE LOWER HILLSBOROUGH RIVER

	Storm Load (lbs./storm)	
	Net Month	Dry Month
. Biochemical Oxygen Demand	0	800
	1,300	1,490
	6,230	2,330
. Chemical Oxygen Demand	7,870	9,980
	9,730	17,200
	14,100	24,000
. Total Nitrogen	163	236
	247	658
	466	1,0[illegible]0
. Total Organic Nitrogen	0	17.9
	19.3	295
	147	570
. Total Phosphorus	73.0	76.8
	122	123
	223	174
. Total Lead	32.0	35.1
	72.6	72.2
	155	115

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-11: TYPICAL WET AND DRY SEASON SINGLE STORM LOAD RESPONSES FOR DIRECT DISCHARGE TO HILLSBOROUGH BAY

	Storm Load (lbs./storm)	
	Net Month	Dry Month
. Biochemical Oxygen Demand	62.0	558
	810	858
	3,320	1,390
. Chemical Oxygen	31,400	34,800
	33,500	37,300
	36,600	41,500
. Total Nitrogen	270	366
	342	540
	470	749
. Total Organic Nitrogen	0	89.3
	50.6	187
	148	351
. Total Phosphorus	319	324
	381	382
	508	446
. Total Lead	91.7	95.6
	143	144
	247	196

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-12: TYPICAL WET AND DRY SEASON SINGLE STORM LOAD RESPONSES FOR THE TAMPA URBAN AREA

	Storm Load (lbs./storm)	
	Net Month	Dry Month
. Biochemical Oxygen Demand	62.0	1,840
	2,940	3,240
	13,800	5,220
. Chemical Oxygen Demand	47,300	53,700
	51,800	67,300
	60,700	82,700
. Total Nitrogen	505	699
	696	1,550
	1,160	2,390
. Total Organic Nitrogen	0	121
	80.1	655
	369	1,280
. Total Phosphorus	501	511
	634	636
	904	773
. Total Lead	149	158
	259	259
	480	372

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-13: TYPICAL WET AND DRY SEASON CUMULATIVE MONTHLY STORM LOADS

	Cumulative Monthly Storm Load (lbs./month)	
	Wet Month	Dry Month
. Biochemical Oxygen Demand	9,860	2,250
	15,600	3,710
	9,720	2,140
	35,200	8,100
. Chemical Oxygen Demand	103,000	32,000
	117,000	43,000
	402,000	93,100
	622,000	168,100
. Total Nitrogen	1,290	881
	2,960	1,640
	4,100	1,350
	8,350	3,880
. Total Organic Nitrogen	123	434
	231	737
	607	467
	960	1,640
. Total Phosphorus	1,560	327
	1,460	308
	4,580	956
	7,600	1,590
. Total Lead	516	109
	871	180
	1,720	359
	3,110	648

Note: Values represent loads from the Reservoir, Lower River, Direct Bay Discharge and the entire Tampa Urban Area.

In order to develop total monthly pollutant loads, the loads determined using the six predictive models for each storm event must be combined with the dry day loads or more appropriately, base flow loads. The development of base flow loads utilized the mean base flow rate values (cfs) from the base flow hydrologic predictive models and the mean concentration values for the six pollutants.

The USGS urban study data base contains extensive measurements of specific pollutant concentrations for nine urban basins. This information for all basins and all measurements has been analyzed to determine mean concentration values and the results of the analysis are presented below.

Parameter	Number of Samples	Concentration (mg/l) Mean
Biochemical Oxygen Demand	35	5.5
Chemical Oxygen Demand	24	58
Total Nitrogen	24	1.7
Total Organic Nitrogen	34	1.0
Total Phosphorus	33	0.25
Total Lead	19	0.104

The base flow load predictions for both wet and dry months have been analyzed for minimum, mean and maximum load values for each of the six constituents. Tables A-14, A-15, and A-16 contain estimated base flow load summaries for each of the three major drainage areas. Table A-17 displays the estimated monthly loads due to the base flow contribution.

Estimating suspended solids loading from urban runoff was the most difficult aspect of these preliminary load estimates. Many attempts have been made by other investigators to relate suspended solids concentrations/loads in multiple land use, urban basins to physical and environmental basin factors. However, due to the highly variable nature of suspended solids sources, these efforts have met with limited success and produced fair to poor correlations between predicted and observed loads.

TABLE A-14: TYPICAL WET AND DRY SEASON BASE FLOW LOAD RESPONSES FOR THE HILLSBOROUGH RIVER RESERVOIR

	Pollutant Load (lbs./month)	
	Wet Month	Dry Month
. Biochemical Oxygen Demand	284	169
	430	264
	1,030	533
. Chemical Oxygen Demand	3,000	1,780
	4,530	2,780
	10,800	5,630
. Total Nitrogen	88	52
	133	81
	319	165
. Total Organic Nitrogen	52	31
	78	48
	190	97
. Total Phosphorus	13	8
	20	12
	47	24
. Total Lead	5	3
	8	5
	19	10

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-15: TYPICAL WET AND DRY SEASON BASE FLOW LOAD RESPONSES FOR THE LOWER HILLSBOROUGH RIVER

	Pollutant Load (lbs./month)	
	Wet Month	Dry Month
. Biochemical Oxygen Demand	640	382
	960	586
	1,640	930
. Chemical Oxygen Demand	6,760	4,040
	10,100	6,190
	17,300	9,820
. Total Nitrogen	198	176
	297	181
	506	287
. Total Organic Nitrogen	116	70
	174	107
	298	169
. Total Phosphorus	29	17
	44	27
	74	42
. Total Lead	18	7
	18	17
	31	18

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-16: TYPICAL WET AND DRY SEASON BASE FLOW LOAD RESPONSES FOR THE DIRECT DISCHARGE TO HILLSBOROUGH BAY

	Pollutant Load (lbs./month)	
	Wet Month	Dry Month
. Biochemical Oxygen Demand	722 901 1,940	433 664 1,050
. Chemical Oxygen Demand	7,630 9,500 20,500	4,670 7,000 11,000
. Total Nitrogen	223 278 598	134 205 325
. Total Organic Nitrogen	132 164 354	79 121 192
. Total Phosphorus	33 41 89	20 30 48
. Total Lead	14 17 37	8 13 20

Note: Values represent the minimum, mean, and maximum load values from the two-month sample periods.

TABLE A-17: TYPICAL WET AND DRY SEASON BASE FLOW MONTHLY LOADS

	Cumulative Load (lbs./month)	
	Wet Month	Dry Month
. Biochemical Oxygen Demand	13,100	8,020
	29,300	17,800
	27,400	20,200
	69,700	46,100
. Chemical Oxygen Demand	137,000	85,000
	308,000	188,000
	289,000	213,000
	735,000	485,000
. Total Nitrogen	4,040	2,480
	9,030	5,520
	8,500	6,270
	21,600	14,300
. Total Organic Nitrogen	2,380	1,460
	5,300	3,250
	4,980	3,680
	12,700	8,390
. Total Phosphorus	595	365
	1,330	811
	1,240	917
	3,160	2,100
. Total Lead	247	152
	552	338
	518	382
	1,320	871

Note: Values represent loads from the Reservoir, Lower River, Direct Bay Discharge and the entire Tampa Urban Area.

The USGS Tampa Urban Study did not analyze suspended solids concentrations in the samples collected. Some storm event data is available from the USGS Miami urban study, but is limited to homogenous land use basins and cannot be directly applied to the Tampa Urban Area basins. Therefore, other data sources were reviewed to define preliminary load values.

Urban runoff data collected in the greater Houston urban area during an investigation by Rice University (EPA-600/2-79-0506) indicated a fair correlation between suspended solids contributions and land use for urban basins with land use characteristics similar to the basins in the Tampa Urban Area. This relationship was described in the following form:

$$SS\ (\text{lbs./acre}) = 42.65\ RO\ (\text{inches}),$$

where the runoff (RO) represents the total runoff volume in acre-feet divided by the drainage area in acres. This relationship can also be expressed in a form where RV represents the runoff volume in acre-feet and the load is represented in total pounds for the event:

$$SS\ (\text{lbs./event}) = 511.8\ RV\ (\text{acre-feet/event}),$$

where RV is predicted by the hydrologic basin response model for storm runoff. Based upon the lack of local information or a better Florida-based correlation, this relationship was used to predict suspended solids storm load responses for the 13 multiple land use urban basins in Tampa.

Predicting suspended solids loads for the base flow component was accomplished through utilizing a mean suspended solids concentration and the predicted base flow for days without storm events. The mean concentration was deterimed from mean annual suspended solids concentrations obtained by the Hillsborough County Environmental Protection Commission for selected water courses in and adjacent to the Tampa Urban Area. Specific monitoring data used for this evaluation were:

	Mean Annual Suspended Solids Concentrations (mg/l)				
Monitoring Station	1975	1976	1977	1978	Station Average 1975-1978
103	25.4	-	39.5	13.6	26.2
104	18.3	-	45.5	17.5	27.1
105	30.1	-	13.5	8.7	17.4
106	3.3	-	4.0	3.9	3.7
109	25.2	-	46.7	24.8	32.2
110	23.3	-	42.1	20.1	28.5
133	-	13.7	20.0	13.7	15.8
134	-	12.8	24.0	-	18.4
Annual Average	22.6	13.3	29.4	14.6	19.97

The mean annual value for all stations was 19.97 mg/l and was used for estimating base flow loads. By means of comparison analysis of unpublished 1980 urban base flow suspended solids concentration data collected in the Lower Village Creek basin in Jefferson County, Alabama (current Birmingham Regional Planning Commission 208 Study) indicated a mean concentration of 20.8 for 39 samples collected over a 3-month period. Although this correlation is not conclusive due to the difference in physiogeologic characteristics between the regions, the comparison is supportive of this value determined from local sources.

Specific load responses for individual storm events and daily base flow variations are shown in Table A-18. Monthly loads for each of the three major drainage areas and the entire Tampa Urban Area are summarized in Table A-19.

TABLE A-18: TYPICAL WET AND DRY SEASON SUSPENDED SOLIDS LOAD RESPONSES FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA

	Daily or Single Storm Loads (lbs./day)	
	Wet Month	Dry Month
Directly to Hillsborough River Reservoir		
. Storm Events	174	246
	1,430	1,550
	4,400	2,210
. Base Flows	1,030	614
	1,560	958
	3,750	1,940
Directly to Lower Hillsborough River		
. Storm Events	998	1,420
	8,080	8,960
	25,100	18,100
. Base Flows	2,330	1,390
	3,490	2,130
	5,950	3,380
Directly to Hillsborough Bay		
. Storm Events	440	614
	3,430	3,850
	10,900	7,880
. Base Flows	2,630	1,570
	3,270	2,410
	7,050	3,820

Note: Values represent minimum, mean and maximum values from the two-month sample periods.

TABLE A-19: CUMULATIVE MONTHLY SUSPENDED SOLIDS LOADS FOR TYPICAL WET AND DRY MONTH FOR THE MAJOR DRAINAGE AREAS AND THE TAMPA URBAN AREA

	Typical Cumulative Monthly Loads (lbs./month)	
	Wet Month	Dry Month
Directly to Hillsborough River Reservoir		
. Base Flow	47,400	29,100
. Storm Events	17,200	3,880
. Combined	64,600	33,000
Directly to Lower Hillsborough River		
. Base Flow	106,000	64,800
. Storm Events	97,000	22,400
. Combined	203,000	87,200
Directly to Hillsborough Bay		
. Base Flow	104,000	73,300
. Storm Events	41,200	9,630
. Combined	145,000	82,900
Entire Tampa Urban Area		
. Base Flow	257,400	167,000
. Storm Events	155,400	35,900
. Combined	410,400	203,000

River Input Analysis

The last aspect of methodology used in defining load characteristics was the technique used for evaluating the hydrologic and load contributions of Hillsborough River to the Reservoir for typical wet and dry months. These values complete the definition of cumulative hydrologic and pollutant loads from the Fowler Avenue Bridge to the Bay.

Analysis of flows in the Hillsborough River was based upon published USGS annual flow records for the following stations:

02303330	Hillsborough River at Morris Bridge
02303350	Trout Creek near Sulphur Springs
02303800	Cypress Creek near Sulphur Springs

Mean monthly flow data for each of these stations for water years 1976 through 1979 were combined to arrive at an estimate of the mean monthly flow of the Hillsborough River at Fowler Avenue. This period of record was selected in order to be consistent with the water quality assessment being conducted under TASK 1.3d - Receiving Water Study.

Each month in this study period was evaluated in terms of relative mean monthly flow rates and cumulative monthly precipitation values and then designated as wet or dry months. Based on the 48-month period, the following results were obtained:

	Monthly Cumulative Precipitation (in.)	Mean Monthly Flow	
		Wet Months (cfs)	Dry Months (cfs)
Minimum Value	0.01	70.7	49.4
Average Value	3.89	669	178
Maximum Value	17.64	2,820	1,040
Range	17.63	2,750	990

The wet months were separated from the four years of data and anlyzed for mean values and variability. Water quality information collected at the Fowler Avenue bridge by the Hillsborough County Environmental Protection Commission was also evaluated for the 15 wet months and 33 dry months to develop monthly loads which, in turn, analyzed for variability and mean values.

Additionally, the relationships between the various nitrogen species for the Hillsborough River at the two stations immediately upstream of the reservoir during the four calendar years 1975-1978 were evaluated. Data were available for total kjeldahl nitrogen and nitrate nitrogen, however, no data was collected on nitrite nitrogen. An estimate of total nitrogen in the Hillsborough River immediately upstream of the reservoir was necessary in order to evaluate the impacts of urban runoff on the subsequent reaches of the river and on Hillsborough Bay.

Total nitrogen is defined by the following relationship between the concentration of the various nitrogen species:

$$TN = TKN + NO_3\text{-}N + NO_2\text{-}N$$

Generally, the nitrite component of natural waters is relatively small. Since no nitrite nitrogen data were available, nitrite nitrogen assumed to be equal to zero. Therefore,

$$TN = TKN + NO_3\text{-}N$$

The available data was analyzed utilizing two specific relationships which evaluate the ratio between total kjeldahl nitrogen and total nitrogen (as determined by the modified TN equation), and a factor which can be multiplied by the total kjeldahl nitrogen concentrations or loads to estimate total nitrogen concentrations or loads. These relationships are:

$$\text{Ratio} = TKN/(TKN + NO_3\text{-}N)$$

$$\text{Factor} = 1/\text{Ratio}$$

The results of analyzing these relationships between the total kjeldahl and nitrate nitrogen species are:

TABLE A-20: TYPICAL SEASONAL MEAN MONTHLY FLOWS CUMULATIVE PRECIPITATION AND POLLUTANT LOADS FOR HILLSBOROUGH RIVER AT FOWLER AVENUE

Date	Cumulative Monthly Precipitation (in)	Mean Monthly Flow (cfs)	(MGD)	BOD	SS	TKN	TP
Wet Season							
7-77	5.36	71	45.9	459	-	149	195
8-77	5.98	118	76.3	573	1270	140	662
2-78	5.17	937	606	0	35400	606	1410
4-78	5.00	108	69.8	582	582	99.0	175
7-78	5.85	361	233	1360	3890	272	1250
8-78	5.97	1098	704	5280	23500	528	3460
Average	5.56	448	290	1380	12900	299	1190

TABLE A-20: TYPICAL SEASONAL MEAN MONTHLY FLOWS CUMULATIVE PRECIPITATION AND POLLUTANT LOADS FOR HILLSBOROUGH RIVER AT FOWLER AVENUE (cont'd)

Date	Cumulative Monthly Precipitation (in)	Mean Monthly Flow (cfs)	Mean Monthly Flow (MGD)	BOD	SS	TKN	TP
Dry Season							
11-76	1.59	85	54.9	641	-	91.6	101
12-76	2.05	98	63.3	1160	-	127	195
2-77	2.41	182	118	1080	5890	510	324
11-77	1.89	90	58.2	1210	970	621	126
3-78	2.44	735	475	3170	7930	595	1110
6-78	2.03	108	69.8	582	1160	146	367
Average	2.07	216	140	1310	3990	348	371

Average Monthly Concentration

HCEPC Station	Calendar Year	TKN (mg/ln)	NO_3-N (mg/ln)	Composite Ratio	Resultant Factor
106	1975	0.445	0.338	0.568	1.761
	1976	0.392	0.900	0.303	3.300
	1977	0.550	0.260	0.679	1.473
	1978	0.100	0.200	0.333	3.003
	Average	0.372	0.425	0.471	2.125
108	1975	1.771	1.276	0.581	1.721
	1976	2.826	1.333	0.679	1.473
	1977	0.670	1.050	0.390	2.564
	1978	0.210	0.500	0.296	3.378
	Average	0.971	1.040	0.487	2.053
106 & 108	Average	0.672	0.733	0.479	2.088

Based upon the results of this analysis, a ratio of 0.479 and a factor of 2.088 were employed in the total nitrogen evaluation. The resultant equation for estimating total nitrogen based on total kjeldahl nitrogen is:

$$TN\ (lbs) = 2.088\ TKN\ (lbs)$$

The typical monthly values for flow and pollutant loads were developed for both wet and dry months. These typical monthly values are:

	Typical Monthly Values	
	Wet Month	Dry Month
Hydrologic Characteristics		
. Mean Monthly Flow Rate (cfs)	669	178
. Mean Monthly Flow Volume (acre-ft.)	40,400	10,700
Pollutant Loads		
. Biochemical Oxygen Demand (lbs.)	127,000	44,700
. Suspended Solids (lbs)	410,000	161,000
. Total Kjeldahl Nitrogen (lbs.)	16,700	8,820
. Total Phosphorus (lbs.)	58,800	15,400
. Total Nitrogen Estimated (lbs.)	34,800	18,400

An analysis of flow and water quality data collected at the dam for the same periods resulted in the mean monthly flow and daily load information. Utilization of the same factor for estimating total nitrogen loads, the following typical wet and dry month loads were developed:

	Typical Monthly Values	
	Wet Month	Dry Month
Hydrologic Characteristics		
. Mean Monthly Flow (cfs)	543	161
. Mean Monthly Flow Volume (acre-feet)	32,800	9,680
Pollutant Loads		
. Biochemical Oxygen Demand (lbs)	143,000	36,700
. Suspended Solids (lbs)	851,000	130,000
. Total Kjeldahl Nitrogen (lbs)	18,500	5,630
. Total Phosphorus (lbs)	44,400	10,000
. Total Nitrogen-Estimated (lbs)	38,500	11,700

It is extremely important to note that the flow in the river, over the dam, is mechanically regulated and determined by the City's water supply needs. These values, which are statistically valid, have been developed for interpretative purposes and do not urport to be representative of probable future releases by the Water Department.

Analysis of monthly water quality in the Alafia River at Bell Shoals Bridge results in an estimate of flows and loads entering the estuarial transition zone prior to significant tidal effects. Monthly flow data collected and published by the USGS for water years 1976-1979 was analyzed for the following stations:

02301500	Alafia River near Lithia
02301600	Lithia Springs at Lithia

Both of these stations are located upstream of the Bell Shoals Bridge (HCEPC Station No. 114) and the specific yield technique was used to estimate Alafia River flow at Station 114. Monthly Lithia Springs discharges were estimated based on periodic USGS measurements and straight-line interpolation between known points. The estimated springs discharge were added to the adjusted Alafia River flow to arrive at monthly flows at Bell Shoals bridge.

Water quality data, collected by HCEPC, was combined with the estimated flows to arrive at monthly loads for the 48-month period which were analyzed for variability and mean monthly load and flow values. Based on this analysis, the following typical monthly load for wet and dry months:

	Typical Monthly Values	
	Wet Month	Dry Month
Hydrologic Characteristics		
. Mean Monthly Flow (cfs)	1,132	461
. Mean Monthly Flow Volume (acre-feet)	68,300	27,800
Pollutant Loads		
. Biochemical Oxygen Demand (lbs)	279,000	116,000
. Suspended Solids (lbs)	1,396,000	697,000
. Total Kjeldahl Nitrogen (lbs)	164,000	38,600
. Total Phosphorus (lbs)	663,000	239,000
. Total Nitrogen-Estimated (lbs)	395,000	92,800

The total nitorgen load estimate is based on an analysis of the predominance and interrelationships of the individual nitrogen species. This analysis was conducted as previously described for the Hillsborough River and resulted in a TN/TKN relationship such that:

TN (lbs) = 2.404 TKN (lbs)

The Point Sources Loads which are summarized in this document represent the most reasonable quantification of individual point source loads based on available permit information and monitoring reports. The loads do not include estimates of pollutants in permitted effluents which are not regulated or discharges which are not permitted. These numbers must be used with the thorough understanding of the manner in which they were acquired, the limitations of the data base, and the implicit and explicit assumptions required for their compilation.

IV. POINT SOURCE POLLUTION

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OBJECTIVE

To identify and quantify pollution sources (except urban runoff from Tampa) to receiving waters in the Hillsborough Bay drainage area from available data.

APPROACH

Two categories of pollution sources will be identified, quantified and evaluated for seasonal variations. One estimate will be made for the total load during an average wet month (June-October) and one for the total load during an average dry month (November-May). Loads will be quantified for pollution parameters that affect the oxygen resources, eutrophication, toxicity and bacterial water quality. Special conditions such as seasonal application of chemicals will be identified.

The first category includes municipal and industrial point sources with NPDES, State, or county permits discharging into Hillsborough Bay and its tributary receiving waters. For each source the average annual and maximum monthly flow and pollutant loads will be listed based on data from the last available record. The pollutants listed will be those identified on the permits. A brief chronology of the past and expected future changes for each major discharge will be presented, where available.

The second category of pollution sources includes those entering the receiving waters from outside the study area. The major sources quantified in this task include the Hillsborough River entering the Hillsborough Reservoir, the Alafia River entering Hillsborough Bay and rural and agricultural runoff entering directly into Hillsborough Reservoir. For each source, flows and loads will be estimated based on available data and, where not available, on literature values.

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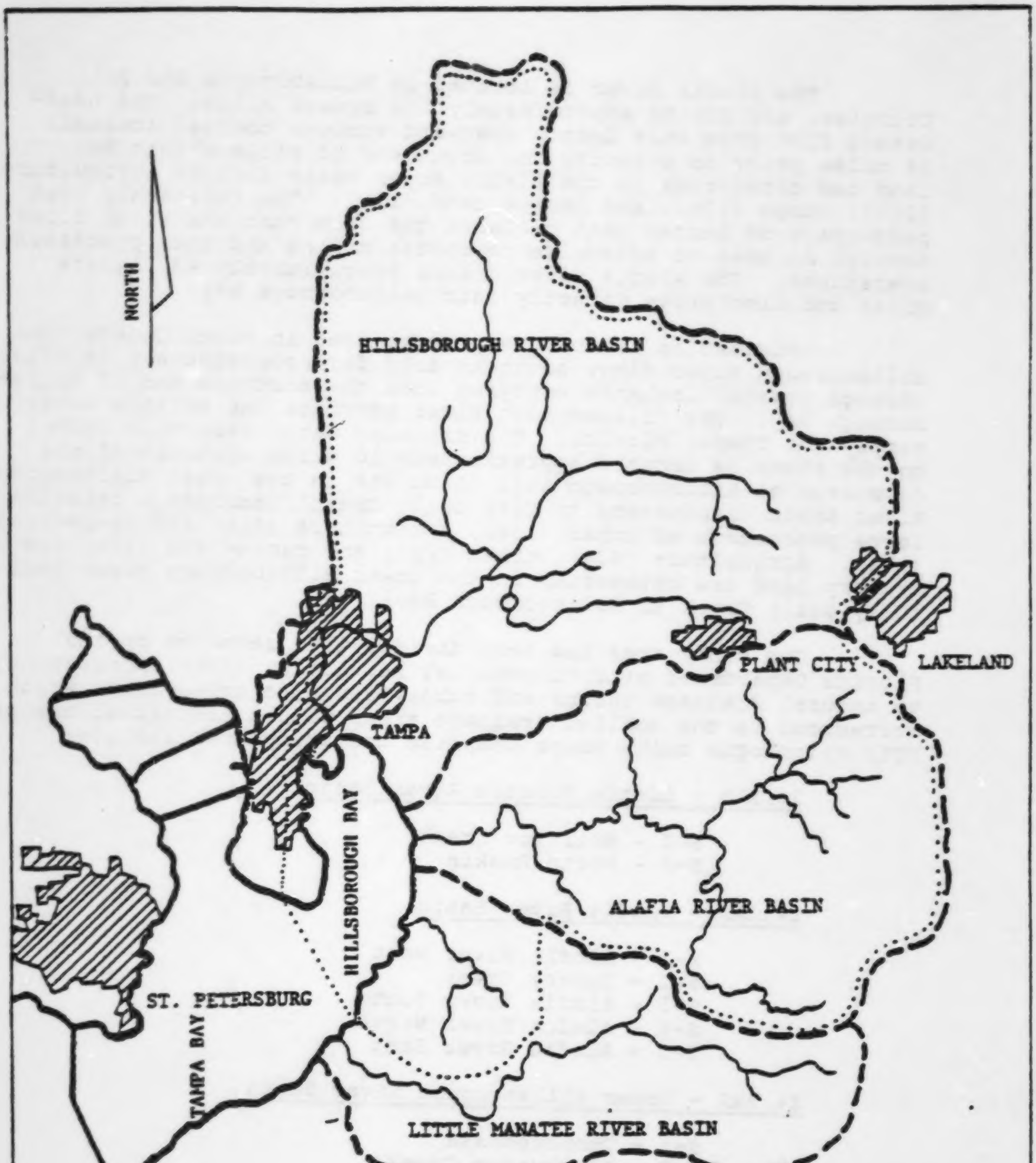
NORTH
HILLSBOROUGH RIVER BASIN
PLANT CITY
LAKELAND
TAMPA
HILLSBOROUGH BAY
ALAFIA RIVER BASIN
ST. PETERSBURG
TAMPA BAY
LITTLE MANATEE RIVER BASIN
BASIN BOUNDARY
STUDY AREA BOUNDARY

FIGURE 1-1: DRAINAGE BASIN BOUNDARIES

R

The Alafia River is located in Hillsborough and Polk Counties, and drains approximately 460 square miles. The headwaters flow from Polk County westward through coastal lowlands 24 miles prior to entering the south end of Hillsborough Bay. Land use categories in the Alafia River basin include agriculture (36%), range (17%), and barren land (12%). The relatively high percentage of barren land reflects the fact that the river flows through an area of extensive phosphate mining and rock processing operations. The Alafia river drains approximately 420 square miles and discharges directly into Hillsborough Bay.

Originating in the Green Swamp area in Pasco County, the Hillsborough River flows southwesterly for approximately 55 miles through coastal lowlands emptying into the northern end of Hillsborough Bay. The Hillsborough River provides the potable water supply for Tampa, Florida. The drinking water reservoir formed on the river is located approximately 10 miles upstream of the discharge to Hillsborough Bay. Land use in the upper Hillsborough River Basin (headwaters to Clay Gully Creek) includes a relatively large percentage of urban (13%), agriculture (52%) and range-land (17%). Agriculture (40%), urban (22%) and range-land (17%) are the primary land use categories in the lower Hillsborough River Basin (Clay Gully Creek to Hillsborough Bay).

The study area has been divided into segments by the Florida Department of Environmental Regulation (FDER) corresponding to natural drainage basins and subdivided into subsegments which correspond to the smaller drainage areas within individual basins. FDER hydrologic units which comprise the study area include:

24.1AA - Little Manatee River Basin

S-2 - Bullfrog Creek
S-6 - North Ruskin

24.2AA - Alafia River Basin

S-1 - Alafia River West
S-2 - Turkey Creek
S-3 - Alafia River South
S-4 - Alafia River North
S-5 - Alafia River East

24.3AA - Upper Hillsborough River Basin

S-1 - Thonotosassa
S-2 - Blackwater Creek
S-3 - Zephyrhills
S-4 - New River

24.3BA - Lower Hillsborough River Basin

S-1 - Tampa
S-2 - Palm River
S-3 - Cypress Creek
S-4 - Trout Creek
S-5 - Hillsborough River

Methodology and Assumptions

Data Acquisition. Point source discharge permits issued by the U. S. Environmental Protection Agency (EPA) and Florida Department of Environmental Regulation (FDER) for both domestic and industrial discharges to waters which are tributary to the Hillsborough River/Hillsborough Bay system have been reviewed. All EPA National Pollutant Discharge Elimination System permits as well as FDER construction/operation permits on file at the FDER District Office in Tampa, Florida, have been inventoried and summarized. This information has been catalogued by stream segment and is contained in the domestic/industrial point source appendix.

Information contained in the permit applications on file at FDER's offices has been entered on the point source discharger summary as "design" conditions. Information contained in FDER compliance monitoring reports and the periodic monitoring reports of the Hillsborough County Environmental Protection Commission (HCEPC) has been entered as "actual" conditions. Permitted point source dischargers within the study area have been organized by the segment and subsegment in which they are located. This method of organization facilitates finding individual dischargers and determining the point source wasteloads contributed to the receiving waters within each subsegment, segment, and ultimately to Hillsborough Bay.

Data Limitations

Three important factors to be considered when using the point source inventory are: (1) the inventory contains only those point sources which are known to State and local agencies and hold valid discharge permits; (2) the discharges are only regulated for specific pollutants by specific industries and that a given industry may be discharging quantities of a pollutant of interest in this study but may not be required to report its concentration and, therefore, is not accounted for in the total basin load; and, (3) that intermittent discharges can not be quantified and may have a substantial impact on total basin loads. Use of the values in this document must include the understanding that this inventory includes evaluation of known quantifiable point sources but does not purport to evaluate all point sources in the three drainage basins.

Data Selection. In most cases, FDER permit files contain more than one set of monitoring reports for a given discharge and often contain State and Federal permits with slightly differing facility operation and design information. In order to better characterize the point source contribution of each discharge, the following information protocal was used:

- Multiple Permits - All permits on file for an individual discharger were examined to determine whether State and Federal permits were for the same discharge or different discharges at the same facility. In cases where both State and Federal permits were issued for the same discharge, the permit chosen was the permit that most accurately represented the discharge.
- Flow Values - Values of flow for individual facilities were chosen for wasteload calculations so as to be most representative of annual operation. The following hierarchy was used with regard to reported flow values:
    1. Twelve-month average values based on monthly monitoring reports contained in the most recent edition of the FDER "Quick-Look" printout at the local office.
    2. Twelve-month average values as determined by HCEPC based on the most recent computation of HCEPC monthly monitoring program reports.
    3. Monthly average values as contained in FDER "Quick-Look" based on monthly monitoring reports (rarely reported in "Quick-Look" reports).
    4. Average day values as reported on FDER "Quick-Look" reports.
    5. Design ADF values as given in the FDER "Quick-Look" report (rarely reported in "Quick-Look" Reports).
    6. Design monthly flow values as given in FDER "Quick-Look" report (rarely reported).
    7. Design ADF values from FDER permit files.
    8. Design ADF values from HCEPC permit files.

- BOD and SS Values - Concentration values for BOD and SS wasteload calculations were selected according to the following hierarchy:
    1. Twelve-month average values (based on monthly operating reports) as contained in FDER "Quick-Look" report.
    2. Twelve-month average values as calculated by HCEPC based on monthly HCEPC monitoring reports.
    3. Average month values as contained in FDER "Quick-Look" reports.
    4. Average day values as contained in FDER permit files.
- TN and TP Values - Concentration values reported for the various nitrogen and phosphorous species are not generally required by State or Federal permits. Some domestic dischargers are required to report nitrogen and phosphorous values by NPDES permits. Five domestic plants in the study area fall into this category and average values from NPDES quarterly reports (located in permit files at EPA Region IV, Atlanta) have been used for these plants. Default values have been used for all other domestic plants as discussed subsequently.

Domestic Dischargers. The domestic dischargers for each basin are individually described in terms of inventory number, name, design capacity, average daily flow (ADF), treatment process and immediate receiving waters. Additionally, estimates of BOD, SS, TN, TP and UOD are given in lbs/day for all dischargers. Daily BOD and SS loads were estimated using the reported ADF flow rate and average BOD and SS effluent concentrations.

During the Tampa Bay 208 Study, the Tampa Bay Regional Planning Council (TBRPC) contacted various Federal, State and local pollution control agencies in order to establish numerical default values for TN, TKN, and TP for secondary wastewater treatment plants.[a] In an effort to utilize a value which would be consistent and realistic for the Tampa Bay Region, TBRPC elected to use an average value of 20.0 mg/l for determining the TN wasteloads for secondary plants. Also, in reviewing the various values for TP, a value of 6.0 mg/l was established as the average concentration in a seconary effluent and was utilized in the wasteload calculations. Daily loads for TN and TP were generally calculated using these default values and reported ADF. In addition to the four small facilities reporting TN and TP values, wasteloads attributable to the City of Tampa's Hookers Point AWT Plant were based upon operating reports. Discussions and correspondence with the City(b) resulted in the use of 2.72 mg/l TN and 5.54 mg/l TP with a 12-month ADF of 45.95 mgd.

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[a] Tampa Bay Regional Planning Council, Point Sources Inventories for the Tampa Bay Region, St. Petersburg, February, 1977.

FDER calculates wasteloads in terms of ultimate oxygen demand (UOD) which is the amount of oxygen required for complete stabilization of remaining carbonaceous and nitrogenous matter in the wastewater effluent. This includes both the amount of oxygen required for decomposition of organic matter (expressed as carbonaceous biochemical oxygen demand) and nitrification which is the oxidation of ammonia and organic nitrogen to nitrate nitrogen (expressed as nitrogenous biochemical oxygen demand). The UOD of the various domestic sources was calculated by using the following relationship: UOD = 1.43(BOD)+4.57(TKN), where all units are expressed in lbs/day. Generally, default values of 20 mg/l TN and TKN utilized, however, actual monthly average values were used for the City of Tampa's Hookers Point AWT Plant.(b)

Industrial Dischargers. The industrial dischargers for each basin are individually described in terms of inventory number, name, principal industrial activities, design capacity, average daily flow, and immediate receiving waters. Additionally, estimates of BOD, SS, TN, TP, and other parameters specifically listed on the permit are given in lbs/day for all dischargers. Estimates of UOD were not prepared for industrial dischargers due to the complex nature of industrial effluents and lack of adequate effluent monitoring information which would be required for such an estimate.

(b) Monthly Operating Report Summaries, Department of Sanitary Sewers, City of Tampa, September 26, 1980.

SECTION 2

LITTLE MANATEE RIVER BASIN - SEGMENT 24.1AA

Major drainage from this segment, as shown schematically on Figure 2-1, flows to the Little Manatee River which discharges directly to Tampa Bay below the interface with Hillsborough Bay. Tributaries flow into Little Manatee River at regular intervals, giving the river a branched pattern. The largest tributary, South Fork Little Manatee River, originates in northern Manatee County and flows northwest to join Little Manatee about two miles south of Wimauma. The six subsegments contained within 24.1AA are:

S-1	Little Manatee River North
S-2	Bullfrog Creek
S-3	Wimauma
S-4	Little Manatee River South
S-5	Piney Point
S-6	North Ruskin

Due to the areal extend of the study area, only the Bullfrog Creek (S-2) and Ruskin North (S-6) subsegments have been inventoried since discharge is directly into the Hillsborough Bay system. The remaining subsegments either discharge directly to Tampa Bay or the Little Manatee River and are not of particular interest to this study.

Domestic and industrial point sources dischargers in subsegments S-2 and S-6 within 24.1AA are located on Figure 2-1 and are described in Tables 2-1 and 2-3.

24.1AA S-2 - Bullfrog Creek

Bullfrog Creek and its associated tributaries constitute the dominant aquatic system in this subsegment. Just prior to reaching the Alafia River, Bullfrog Creek turns abruptly to the west and enters Hillsborough Bay at Remlap.

Domestic Point Sources. There are two privately-owned domestic plants which have a total design capacity of 0.02 mgd and presently discharge approximately 0.01 mgd to Bullfrog Creek. There are no municipal domestic dischargers in this subsegment. Tables 2-1 and 2-2 present facility descriptions and wasteloads for the above dischargers.

Domestic point source wasteloads being discharged from Subsegment 24.1AA S-2 include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Bullfrog Creek	0.0124	0.98	1.08	2.07	0.63	10.86

*Wasteloads are in lbs/day.

Industrial Point Sources. There are no permitted industrial dischargers within this subsegment.

24.1AA S-6 - North Ruskin

Hillsborough Bay and the numerous small coastal creeks and canals draining into it comprise the aquatic system in Subsegment 6. All of these streams and canals are short, originating less than three miles from the coast.

Domestic Point Sources. There are three private domestic plants which discharge to Hillsborough Bay. They have a total design capacity of 0.03 mgd and an approximate ADF of 0.02 mgd. There are no municipal domestic dischargers in this subsegment. See Tables 2-1 and 2-2 for details on these dischargers.

Domestic point source wasteloads being discharged from Subsegment 24.1AA S-6 include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Hillsborough Bay	0.0151	0.99	1.49	2.51	0.76	12.89

*Wasteloads are in lbs/day.

Industrial Point Sources. The industrial dischargers are Ruskin Tomato Growers, Inc., Ruskin Vegetable Corporation and Tampa Electric Company's Big Bend Station. Tampa Electric Company holds a NPDES permit with seven discharge points; however, only four of these points discharge under normal circumstances while three points are permitted for intermittent, storm-related discharges which do no have specific volumetric or rate restrictions.

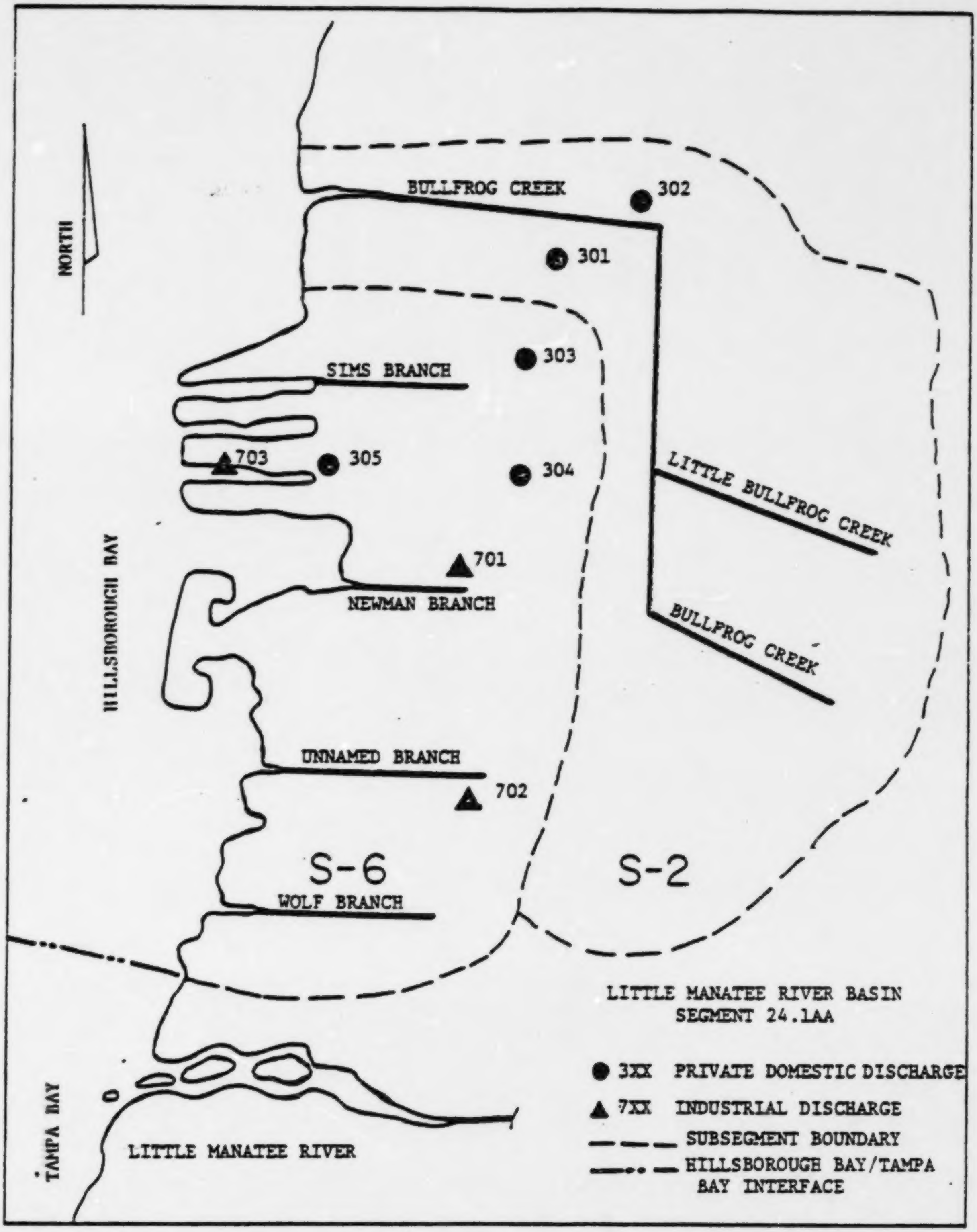
NORTH
BULLFROG CREEK
302
301
303
SIMS BRANCH
703
305
304
LITTLE BULLFROG CREEK
HILLSBOROUGH BAY
701
NEWMAN BRANCH
BULLFROG CREEK
UNNAMED BRANCH
702
S-6
S-2
WOLF BRANCH
LITTLE MANATEE RIVER BASIN
SEGMENT 24.1AA
● 3XX PRIVATE DOMESTIC DISCHARGE
▲ 7XX INDUSTRIAL DISCHARGE
SUBSEGMENT BOUNDARY
HILLSBOROUGH BAY/TAMPA BAY INTERFACE
TAMPA BAY
LITTLE MANATEE RIVER

FIGURE 2-1: LITTLE MANATEE RIVER BASIN
DISCHARGER SEGMENT MAP

TABLE 2-1: DOMESTIC DISCHARGERS
LITTLE MANATEE RIVER BASIN (24.1 AA)

Inventory Number	Name	Design/ADF (mgd)	Treatment Process	Immediate Receiving Waters
·Subsegment S-2--Bullfrog Creek				
Private				
301	Nistal Trailer Park	0.0050/0.0037	Extended Aeration	Bullfrog Creek
302	Twin Oaks Plaza	0.0105/0.0087	Modified AWT	Unnamed Canal
Municipal				
None				
·Subsegment S-6--North Ruskin				
Private				
303	Alafia MHP	0.0200/0.0092	Contact Stabilization	Unnamed Canal to Bay
304	Eastwood Estates MHP	0.0030/0.0029	Contact Stabilization	Unnamed Canal to Bay
305	Tampa Electric Company	0.0045/0.0030	Extended Aeration	Unnamed Ditch to Bay
Municipal				
None				

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TABLE 2-2: DOMESTIC WASTELOADS
LITTLE MANATEE RIVER BASIN (24.1AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-2						
301	0.0037	00.21	00.19	0.62	0.19	3.13
302	0.0087	0.77	0.89	1.45	0.44	7.73
S-2	0.0124	0.98	1.08	2.07	0.63	10.86
Subsegment S-6						
303	0.0092	0.59	1.07	1.53	0.46	7.84
304	0.0029	0.09	0.11	0.48	0.15	2.32
305	0.0030	0.31	0.31	0.50	0.15	2.73
S-6	0.0151	0.99	1.49	2.51	0.76	12.89
Basin Total	0.0275	1.97	2.57	4.58	1.39	23.75

TABLE 2-2: DOMESTIC WASTELOADS
LITTLE MANATEE RIVER BASIN (24.1AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-2						
301	0.0037	00.21	00.19	0.62	0.19	3.13
302	0.0087	0.77	0.89	1.45	0.44	7.73
S-2	0.0124	0.98	1.08	2.07	0.63	10.86
Subsegment S-6						
303	0.0092	0.59	1.07	1.53	0.46	7.84
304	0.0029	0.09	0.11	0.48	0.15	2.32
305	0.0030	0.31	0.31	0.50	0.15	2.73
S-6	0.0151	0.99	1.49	2.51	0.76	12.89
Basin Total	0.0275	1.97	2.57	4.58	1.39	23.75

TABLE 2-3: INDUSTRIAL DISCHARGERS
LITTLE MANATEE RIVER BASIN (24.1AA)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
·Subsegment S-2--Bullfrog Creek				
None				
·Subsegment S-6--North Ruskin				
701	Ruskin Tomato Growers	Vegetable Washing & Shipping	0.0065/0.0020	Newman Creek to Bay
702	Ruskin Vegetable Corp.	Vegetable Washing & Shipping	-/-	Unnamed ditch to Bay
703.001	Tampa Electric Co.	Freshwater waste streams	-/340	Hillsborough Bay
703.002	"	Ash pond runoff	-/-	"
703.003	"	Boiler blowdown	-/270	"
703.004	"	Plant stormwater runoff	-/316	"
703.005	"	Boiler blowdown	-/0.0515	"
703.006	"	Material storage runoff	-/0	"
703.007	"	Construction runoff	-/0	"

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TABLE 2-4 : INDUSTRIAL WASTELOADS
LITTLE MANATEE RIVER BASIN (24.1 AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				Other Parameters
		BOD	SS	TN	TP	
Subsegment S-2						
None	--	--	--	--	--	--
Subsegment S-6						
703.001	256.1	--	--	--	--	RC, FC, T
703.003	287.5	--	--	--	--	RC, FC, T
703.004	282.3	--	--	--	--	RC, FC, T
S-6	825.95					
Basin Total	825.95	--	--	--	--	

SECTION 3

ALAFIA RIVER - SEGMENT 24.2AA

Major drainage from this segment flows into the Alafia River which discharges directly into Hillsborough Bay. The discharge rate of the Alafia River historically averages 329 cfs at Lithia Springs (1960-77) and 364 cfs for 1978-79 (USGS). Surface runoff contributes a substantial portion of the flow. Major tributaries of the Alafia River include the North Prong, South Prong, and the Little Alafia River. The North Prong drains approximately 135 square miles and historically contributes a flow of roughly 154 cfs to the Alafia River and 364 cfs during 1978-79 (USGS). Flow from the South Prong of the Alafia averages 116 cfs (1960-77) with an average of 65.6 cfs reported in 1978 (USGS) from a 107 square mile drainage area. Just downstream of the confluence of the North and South Prong of the Alafia, Lithia Springs enters the main river with an average flow of 51 cfs. In addition to the large phosphate operations, major sources of pollution in this area include runoff from mined areas, pasture and agricultural land; and occasional slime spills from phosphate operations.

This hydrologic segment is shown schematically on Figure 3-1. The subsegments within this segment correspond to natural drainage basins. All the waters enter Hillsborough Bay through the Alafia River. The five subsegments contained within 24.2AA are:

S-1	Alafia River West
S-2	Turkey Creek
S-3	Alafia River South
S-4	Alafia River North
S-5	Alafia River East

In order to simplify the evaluation of wasteloads, subsegments S-2 thru S-5 have been combined into one segment which is referred to as S-X. The land use delineation for all of the included segments are similar and the monitoring stations are located in a manner which permits this combination.

Domestic and industrial point source dischargers in 24.2AA are located on Figure 3-1 and are described in Tables 3-1 and 3-3.

24.2AA S-1 - Alafia River West

This subsegment represents the only developed area in the Alafia River Basin and contains a large chemical manufacturing facility.

Domestic Point Sources. There is one private domestic plant discharging approximately 0.013 mgd to the Alafia River. There are no municipal dischargers in this subsegment. Tables 3-1 and 3-2 present the details for this discharger.

Domestic point source wasteloads being discharged from Subsegment 24.2AA S-1 include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Alafia River	0.013	0.01	0	0.03	0.01	0.15

*Wasteloads are in lbs/day.

Industrial Point Sources. There are two industrial point sources, a chemical plant and a dairy farm, which discharge in subsegment S-1. However, only the chemical plant discharges continuously. Tables 3-3 and 3-4 describe these facilities and wasteloads.

24.2AA S-X - Alafia River Basin, excluding Subsegment S-1

This combined segment contains extensive phosphate mines and mine holdings with relatively sparse residential development.

Domestic Point Sources. There are no private domestic dischargers and only one municipal point source, the City of Mulberry. Refer to Tables 3-1 and 3-2 for describing this discharger.

Domestic point source wasteloads being discharged from Subsegment 24.2AA S-X include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
North Prong - Alafia River	0.026	22	-	43	13	230

*Wasteloads are in lbs/day.

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Industrial Point Sources. With the exception of a railroad boxcar cleaning facility, all industrial discharges are due to the mining, processing and enrichment of phosphate ore. Continuous process streams have been evaluated but many of the permitted discharges are intermittent and could not be evaluated. Tables 3-3 and 3-4 present brief facility descriptions and summary wasteloads.

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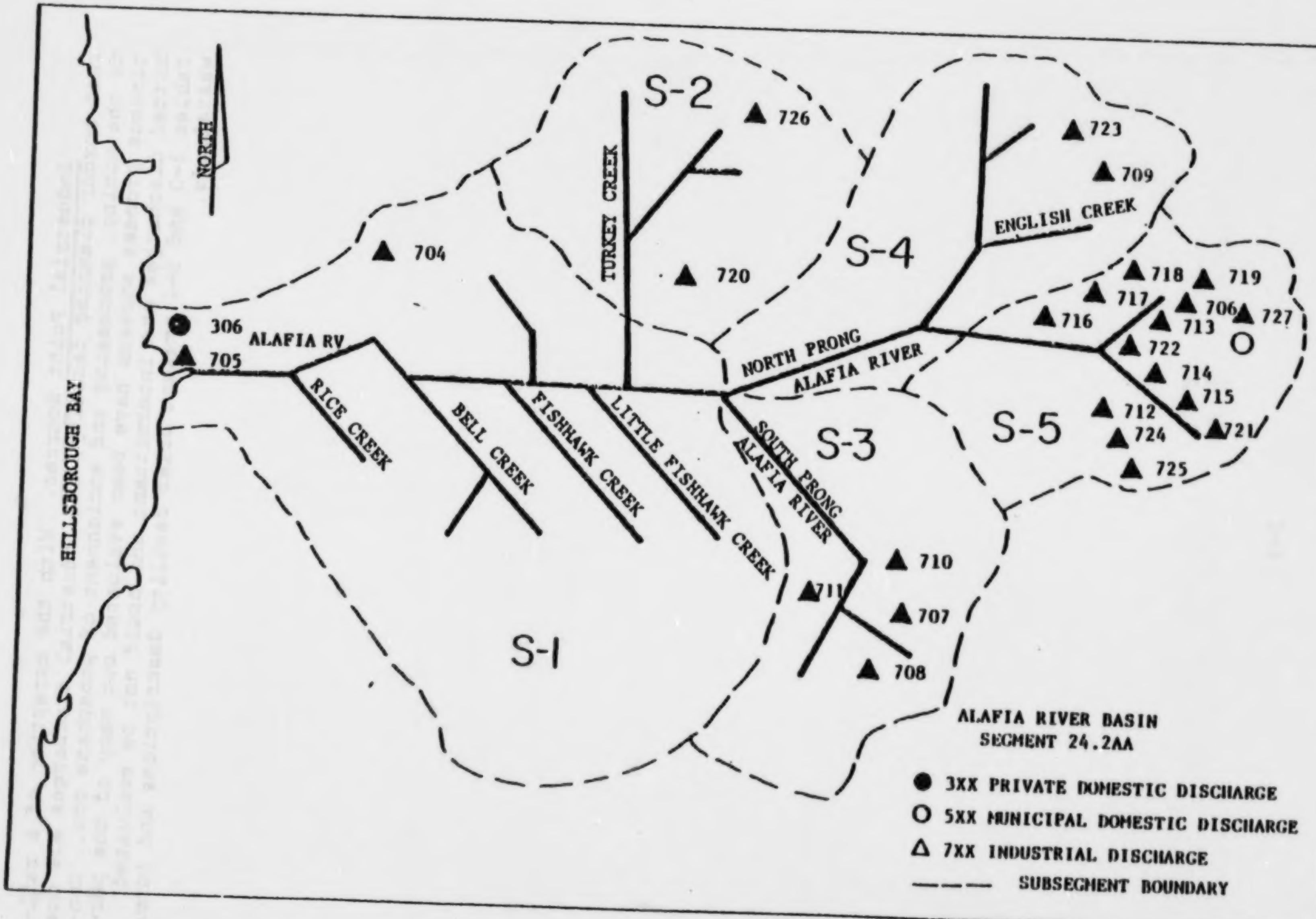
NORTH
HILLSBOROUGH BAY
306
705
ALAFIA RV
704
RICE CREEK
BELL CREEK
FISHHAWK CREEK
LITTLE FISHHAWK CREEK
TURKEY CREEK
S-1
S-2
S-3
S-4
S-5
726
720
NORTH PRONG
ALAFIA RIVER
SOUTH PRONG
ALAFIA RIVER
ENGLISH CREEK
723
709
718
719
717
706
727
716
713
722
714
715
712
724
721
725
710
711
707
708
ALAFIA RIVER BASIN
SEGMENT 24.2AA
● 3XX PRIVATE DOMESTIC DISCHARGE
○ 5XX MUNICIPAL DOMESTIC DISCHARGE
△ 7XX INDUSTRIAL DISCHARGE
— — — SUBSEGMENT BOUNDARY

FIGURE 3-1: ALAFIA RIVER BASIN
DISCHARGER SEGMENT MAP

TABLE 3-1: DOMESTIC DISCHARGERS
ALAFIA RIVER BASIN (24.2 AA)

Inventory Number	Name	Design/ADF (mgd)	Treatment Process	Immediate Receiving Waters
·Subsegment S-1--Alafia River West				
Private				
306	Gardinier Inc.	0.0125/0.002	M60 Septic Tank-Sand Filter to Retention Pond	Alafia River
Municipal				
None				
·Subsegment S-x--Alafia River Basin excluding Subsegment S-1				
Private				
None				
Municipal				
501	City of Mulberry	0.500/0.260	Extended Aeration	North Prong of Alafia River

TABLE 3-2: DOMESTIC WASTELOADS
ALFIA RIVER BASIN (24.2 AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-1						
306	0.013	0.01	0.00	0.03	0.01	0.15
S-1	0.013	0.01	0.00	0.03	0.01	0.15
Subsegment S-X						
501	0.2600	22.00	--	43.37	13.01	229.66
S-X	0.2600	22.00	--	43.37	13.01	229.66
Basin Total	0.2602	22.00	0.00	43.40	13.02	229.81

TABLE 3-3: INDUSTRIAL DISCHARGERS
ALAFIA RIVER BASIN (24.2 AA)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
Subsegment S-1				
704	Florida Dairy	Feed Lot	-/-	Hillsborough Bay
705	Gardinier, Inc.	Chemical Mfg.	-/66.3	Hillsborough Bay and Alafia River
Subsegment S-X				
706	Agrico Chemical Co.	Phosphate Milling	-/-	Alafia River North Prong
707	" " "	Mine	-/-	Alafia River South Prong
708	Borden, Inc.	Big Four Mine	-/4.26	" "
709	" "	Coronet Mine	-/-	English Creek
710	Brewster Phosphate	Haynesworth Mine	0.005/-	Alafia River South Prong
711	" "	Fort Lonesome Mine	-/14.57	" "
712	C.F. Chemicals, Inc.	Phosphate Complex	-/3.32	Alafia River
713	Conserv	Mine	-/14.0	Thirty Mile Cr.
714	Electro-Phos. Corp.	Chemical Mfg.	-/-	Alafia River North Prong
715	Estech General Chem. Corp.	Silver City Mine	-/1.8	Alafia River South Prong
716	Farmland Industries	Chemical Mfg.	-/3.27	Alafia River North Prong

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TABLE 3-3: INDUSTRIAL DISCHARGERS
ALAFIA RIVER BASIN (24.2 AA) (Cont'd)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
Subsegment S-X (Cont'd)				
717	W. R. Grace & Co.	Chemical Mfg.	-/10.09	Alafia River South Prong
718	" "	" "	-/4.67	Alafia River
719	" "	" "	-/6.68	Alafia River North Prong
720	Hopewell Land Corp.	Recovery Plant	-/4.42	Alafia River
721	IMC Corp.	Chemical Mfg.	-/1.44	Alafia River South Prong
722	"	Kingsford Mine	-/6.70	" "
723	Mid-Florida Phosphate Corp.	Chemical Mfg.	-/-	Alafia River North Prong
724	Mobile Chem. Co.	Nichols Mine	-/12.9	Thirty Mile Branch
725	" "	Chemical Mfg.	-/-	" "
726	Seaboard Coastline R.R.	Freight Car Yard	-/0.017	Winston Creek
727	T/A Minerals	Sands & Rock Mining	-/-	Alafia River North Prong

TABLE 3-4: INDUSTRIAL WASTELOADS
ALFIA RIVER BASIN (24.2 AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				Other Parameters
		BOD	SS	TN	TP	
Subsegment S-1						
705.001	31.2	--	--	--	--	pH, T, Zn, RC, Cr
705.005	19.0	--	--	--	--	pH, T, Zn, RC, Cr
705.008	0.67	--	67.2	--	155.1	Ra
705.009	14.66	--	1332.7	--	85.6	Ra
705.012	0.77	--	284.3	--	132.1	--
S-1	66.30		1684.2		372.8	
Subsegment S-X						
708.001	4.24	--	139	--	--	pH, F
708.003	0.014	--	1	--	--	pH, F
711.1	7.14	--	480	--	27	pH, F
711.2	7.44	--	1224	--	56	pH, F
713.01	14.00	--	--	--	743	pH, F, Ra
716.001	2.01	--	--	--	431	PH, F, Ra
716.002	1.26	--	--	--	520	pH, F
717.001	10.09	--	926	--	--	pH
718.001	4.67	--	748	--	155	pH, F
719.002	4.94	--	519	--	77	pH, F
719.003	0.93	--	52	--	19	pH, F
719.004	0.81	--	71	--	10	pH, F
721.002	1.44	--	150	--	6.2	pH, F
722.001	0.20	--	3.7	--	0.8	pH, F
722.002	1.41	--	71	--	10.8	pH, F
722.003	3.73	--	249	--	14.6	pH, F
722.004	1.77	--	131	--	20.5	pH, F
722.006	0.61	--	156	--	8.0	pH, F
724.001	12.90	--	344	--	87	pH, F
726	0.017	--	2.1	0.31	0.66	pH, F, Ra
S-X	79.62	--	5267	0.31	2187	
Basin Total	145.9	--	6951	0.31	2560	

SECTION 4

UPPER HILLSBOROUGH RIVER BASIN - SEGMENT 24.3AA

This segment drains the northeast corner of Hillsborough County, the southeast corner of Pasco County, and the western portion of Polk County (Figure 4-1). The basin includes the upper Hillsborough River area from the drainage divide with the Withlacoochee River, west to the New River basin, south to the unincorporated town of Brandon, then east on a line just south of Plant City. The major water bodies are New River, Blackwater Creek, the Upper Hillsborough River and the Flint-Pemberton Creek drainage system. The primary sources of pollution in this reach of the Hillsborough River consist of urban and agricultural runoff, domestic sewage and industrial discharges primarily from citrus processing plants. The four subsegments contained within 24.3AA are:

S-1	Lake Thonotosassa
S-2	Blackwater Creek
S-3	Zephyrhills
S-4	New River

Domestic and industrial point source dischargers in 24.3AA are located on Figure 4-1 and are described in Tables 4-1 and 4-3.

24.3AA S-1 - Lake Thonotosassa

This subsegment is characterized by channelization of formerly natural streams and an associated system of lateral canals and feeder ditches which have allowed urban and agricultural uses to extend from upland areas into wetlands and other low lying areas. Only two streams flow directly into the Hillsborough River: Holloman's Branch, an intermittent stream, and Flint Creek. These tributaries drain the great majority of the subsegment. Flint Creek originates from Lake Thonotosassa which in turn is fed by Baker Creek whose major tributary is Pemberton Creek. Pemberton Creek in turn is joined by Mill Creek and Sparkman Branch. Thus, Flint Creek receives these discharges moderated by the effects of the lake. Another stream, Campbell Branch, flows directly into Flint Creek.

Domestic Point Sources. There are no private domestic dischargers and only one municipal point source within this subsegment. Plant City currently discharges approximately 2.25 mgd of AWT effluent to Mill Creek which is a tributary of Pemberton Creek. The plant is presently designed for 8.0 mgd and utilizes a series of channels stocked with water hyacinth to achieve nutrient removal. Refer to Tables 4-1 and 4-2 for additional information describing the facility and its wasteload.

Domestic point source wasteloads being discharged from this subsegment include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Mill Creek	3.4	142	397	227	17	1240

*Wasteloads are in lbs/day.

Industrial Point Sources. The only industrial discharger is a seafood processing facility in Dover. Tables 4-3 and 4-4 provide specific information describing the facility and its wasteload.

24.3AA S-2 - Blackwater Creek

This subsegment is defined by the portion of the Blackwater Creek watershed located in Hillsborough County. Blackwater Creek, including Itchepackesassa Creek, forms a major tributary of the Hillsborough River.

Domestic Point Sources. There is only one private domestic discharger and no municipal point sources in this subsegment. The privately owned package plant discharges to Blackwater Creek. Tables 4-1 and 4-2 describe the facility and its wasteload.

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Blackwater Creek	0.03	5	-	5	1.5	30

*Wasteloads are in lbs/day.

Industrial Point Sources. Three industrial point sources, one chemical plant and two citrus processing facilities, discharge approximately 0.81 mgd to the subsegment. Tables 4-3 and 4-4 present further information on the facilities and their wasteloads.

24.3AA S-3 - Zephyrhills

The lower portion of this subsegment lies immediately upstream of Blackwater Creek while the upper portion extends above the City of Zephyrhills. The basin includes the northern portion of the Hillsborough River and its tributaries: Fox Branch, Big Ditch, Crystal Springs and an unnamed tributary just west of SR 156 on the outskirts of Zephyrhills. A sizeable canal system drains the area in and around Zephyrhills Army Air Base and discharges into the Hillsborough River system through an unchannelized fringe of the hardwood swamp forest that lies in the lower half of the subsegment. A low-lying marshy strand within Zephyrhills' urban area (including Lake Zephyr) undoubtedly receives storm runoff, probably including some domestic wastes, and directs the flow southerly through an unchannelized canal that discharges into the Hillsborough River.

Domestic Point Sources. There are no domestic point source discharges in subsegment S-3.

Industrial Point Sources. C. F. Industries, the sole discharger in 24.3AA S-3, discharges 2.0 mgd of process water to Big Ditch, a tributary of the Hillsborough River. Tables 4-3 and 4-4 describe the facility and its wasteload.

24.3AA S-4 - New River

This subsegment consists of the New River and an unnamed tributary on the west both discharging to the Hillsborough River. The Four Rivers Basin Project of the Army Corps of Engineers will construct a levee west of where Trout Creek enters the Hillsborough River, thus creating a large flood detention area. There are no point source dischargers within subsegment 24.3AA S-4.

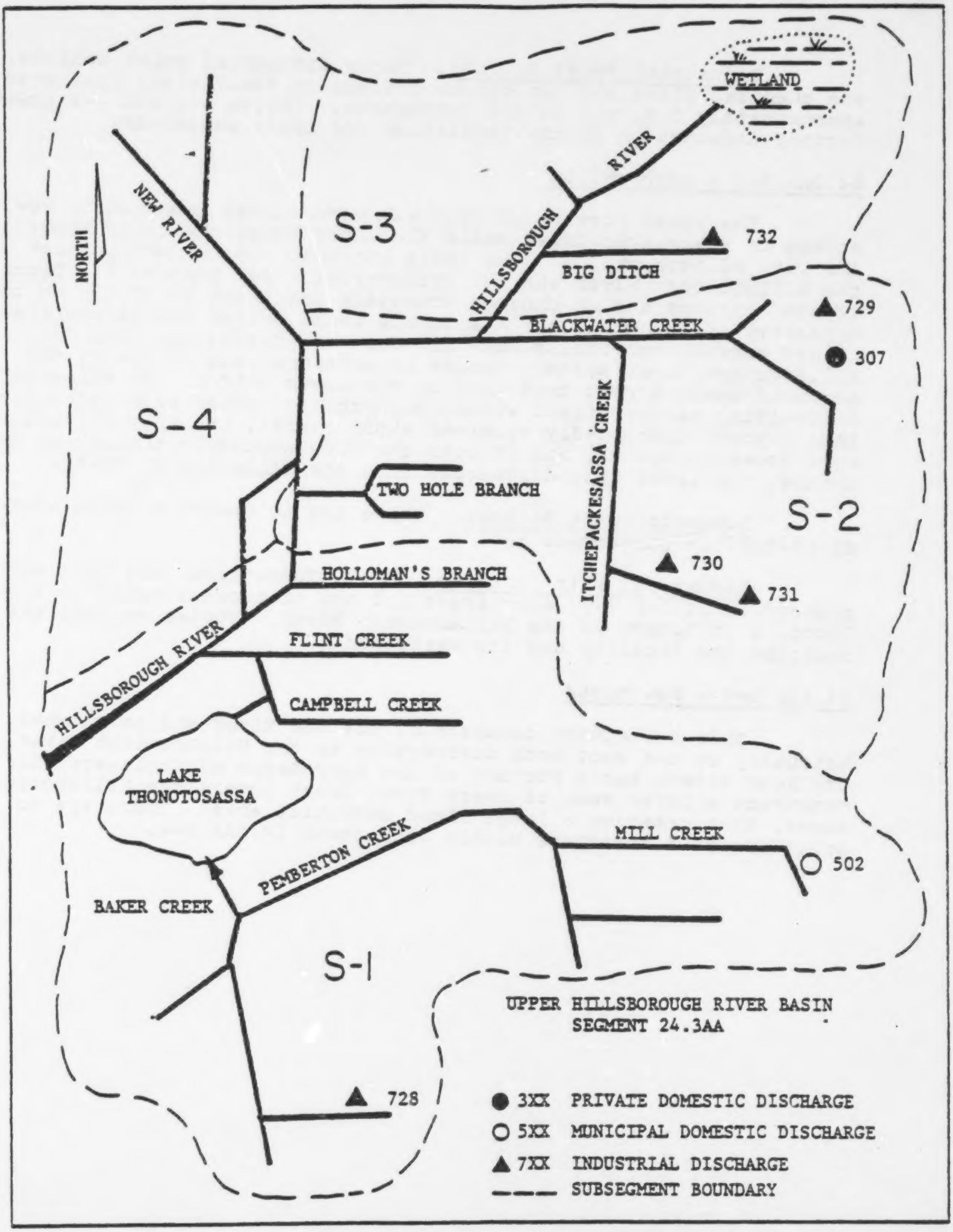
NORTH
NEW RIVER
S-3
HILLSBOROUGH RIVER
WETLAND
732
BIG DITCH
BLACKWATER CREEK
729
307
S-4
ITCHEPACKESASSA CREEK
TWO HOLE BRANCH
S-2
730
731
HOLLOMAN'S BRANCH
HILLSBOROUGH RIVER
FLINT CREEK
CAMPBELL CREEK
LAKE THONOTOSASSA
MILL CREEK
PEMBERTON CREEK
502
BAKER CREEK
S-1
UPPER HILLSBOROUGH RIVER BASIN
SEGMENT 24.3AA
728
● 3XX PRIVATE DOMESTIC DISCHARGE
○ 5XX MUNICIPAL DOMESTIC DISCHARGE
▲ 7XX INDUSTRIAL DISCHARGE
SUBSEGMENT BOUNDARY

FIGURE 4-1: UPPER HILLSBOROUGH RIVER BASIN
DISCHARGER SEGMENT MAP

TABLE 4-1: DOMESTIC DISCHARGERS
UPPER HILLSBOROUGH RIVER BASIN (24.3 AA)

Inventory Number	Name	Design/ADF (mgd)	Treatment Process	Immediate Receiving Waters
·Subsegment S-1--Lake Thonotosassa				
Private				
None				
Municipal				
502	City of Plant City	8.00/3.40	Activated Sludge Water Treatment	Pemberton Creek
·Subsegment S-2--Blackwater Creek				
Private				
307	Meadowbrook Mobile Park	0.0301	Extended Aeration	Hillsborough River
Municipal				
None				
·Subsegment S-3--Zephyrhills				
None				
·Subsegment S-4--New River				
None				

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TABLE 4-2: DOMESTIC WASTELOADS
UPPER HILLSBOROUGH RIVER BASIN (24.3 AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-1						
502	3.4	141.78	396.98	226.85	17.01	1239.45
S-1	3.4	141.78	396.98	226.85	17.01	1239.45
Subsegment S-2						
307	0.030	5.0	--	5.00	1.50	30.00
S-2	0.030	5.0	--	5.00	1.50	30.00
Subsegment S-3						
None	--	--	--	--	--	--
Subsegment S-4						
None	--	--	--	--	--	--
Basin Total	3.430	146.78	396.98	231.85	18.51	1269.45

TABLE 4-3: INDUSTRIAL DISCHARGERS
UPPER HILLSBOROUGH RIVER BASIN (24.3AA)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
Subsegment S-1				
728	Treasure Isle	Seafood Processing	0.800/0.356	Lake Thonotosassa
Subsegment S-2				
729	Alpha Chemical Corp.	Chemical Mfg.	-/0.241	Hillsborough River
730	Kraft, Inc.	Citrus Processing	-/0.50	Itchepackesassa Canal
731	Sunstar Foods, Inc.	" "	-/0.07	"
Subsegment S-3				
732	C.F. Industries	Chemical Mfg.	-/0.194	Hillsborough River

TABLE 4-4: INDUSTRIAL WASTELOADS
UPPER HILLSBOROUGH RIVER BASIN (24.3AA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				Other Parameters
		BOD	SS	TN	TP	
Subsegment S-1						
728	0.36	29.7	22.0	--	--	CF
Subsegment S-2						
729	0.24	--	--	--	--	pH, T
730	0.50	47	226.0	--	--	pH
731	0.07	20.4	2.56	--	--	pH, T
S-2	0.81	67.4	228.6	--	--	
Subsegment S-3						
732.001	2.14	--	294	--	97	pH, F, Ra
732.1	0.42	--	157	--	110	pH, F
S-3	2.56	--	451	--	207	
Subsegment S-4						
None						
Subsegment S-5						
None						
Basin Total	3.73	97.1	701.6	--	207	

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SECTION 5

LOWER HILLSBOROUGH RIVER BASIN - SEGMENT 24.3BA

Segment 24.3BA extends from the Interbay Peninsula and the Alafia River on the south to just west of St. Leo on the north, and from the Land-O-Lakes area on the west to the lower portion of the Hillsborough River State Park on the east (Figures 5-1 and 5-2). Surface drainage is centered around the Hillsborough River with Cypress Creek and its tributaries (Thirteen Mile Run, Bee Tree Branch, Stanley Branch and Bayou Branch, Trout Creek and Clay Gully) entering from the north. Cow House Creek is actually an old cut-through or meander channel of the Hillsborough River. The Hillsborough River drains approximately 650 square miles with discharges near the mouth historically averaging 422 cfs and 332 cfs in 1978-79.

Coastal streams predominate in the southeast portion of the segment, including the Palm River-Six Mile Creek System, Delaney Creek and Archie Creek. Other major hydrologic features are Sulphur Springs, the Eureka Springs area, McKay Bay and Hillsborough Bay. Major hydrologic modifications are the Tampa Water Works Dam, the Tampa Bypass Canal (under construction) and the dredging of the shipping channels in Hillsborough Bay. The five subsegments contained within 24.3BA are:

S-1	Tampa
S-2	Palm River
S-3	Cypress Creek
S-4	Trout Creek
S-5	Hillsborough River

Domestic and industrial point source dischargers in 24.3BA are located on Figures 5-1 and 5-2, with descriptions provided in Tables 5-1 and 5-3.

24.3BA S-1 - Tampa

This subsegment includes most of the City of Tampa, Interbay Peninsula, and Davis Island. Water resources include the Hillsborough River, its tributary Sulphur Springs, McKay Bay and Hillsborough Bay. About 10 miles above the mouth of the Hillsborough River, the Tampa City Water Works Dam creates a reservoir which is used as a water supply source for the City of Tampa. The Tampa Bypass Canal, currently under construction, will divert high water in the area of Cow House Creek and Cypress Creek through the canal where it will be discharged to McKay Bay. Hillsborough Bay and McKay Bay are transected by major channels associated with port facilities and the Tampa Bypass Canal respectively.

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Domestic Point Sources. There are no private domestic dischargers in subsegment S-1. The City of Tampa owns and operates the Hookers Point and Juanita Apartments wastewater treatment plants. The Hookers Point plant has been expanded to 60 mgd capacity with a current 44.72 mgd flow and is designed to achieve FDER and EPA permitted levels of BOD, SS, TN and TP. The Juanita Apartments plant has a total design capacity of 0.01 mgd and discharges approximately 0.004 mgd. Tables 5-1 and 5-2 provide further information desciring facilities and wasteloads.

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Hillsborough Bay	44.72	2101	1056	1020	1252	6183

*Wasteloads are in lbs/day.

The Tampa AWT facility at Hookers Point is the largest domestic point study in the entire study area and is a significant major discharger. At the present time, approximately 44.7 million gallons per day (mgd) of domestic and industrial sewage are treated by the City's sewage treatment plants. This amount has increased from the 13 mgd that was processed when the City first operated the Hooker's Point Sewage Treatment Plant. Effluent from private residences accounted for 32.5 mgd, while industries discharged about 3.5 mgd; an additional 9 mgd is contributed from groundwater leakage and other sources.

The new Hookers Point Advance Waste Treatment Plant has been designed with an initial capacity of 60 mgd, which can be increased to 120 mgd. Presently, it is anticipated that the capacity of Phase I (60 mgd) will be exceeded by about 1990; therefore, Phase II will need to be on line by that time. It is estimated that approximately 75 mgd of sewage effluent will be generated by the year 2000. With an ultimate capacity of 120 mgd, the Hookers Point AWT plant should be able to accommodate the needs of the City's service area well into the 21st Century. In the near future, the USF Interim Plant in north Tampa will be taken off-line in mid-1981 which will result in an increase flow at Hookers Point of approximately 1.6 mgd.

With the start-up of the new AWT plant, the City of Tampa's Sewer Department is in compliance with all current environmental regulations. In the past, the City's sewage treatment plant had been a prime contributor to water-quality problems in Tampa Bay. However, the AWT plant should help to improve the quality of water in Tampa and Hillsborough Bays.

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*Based on FDER Monthly Operating Reports for October 1979-September 1980.

Industrial Point Sources. Nine industries within this subsegment involved in the receipt, storage and distribution of refined oil have been issued NPDES permits for the contaminated wastewater that they discharge from bulk storage tank areas, product transfer areas, and loading and unloading areas. These discharges are a result of clean-up and stormwater runoff and in most cases are directed through an oil/water separator prior to discharge to surface waters. Currently, the NPDES requirements limit the average daily oil and grease concentration of the discharge to less than 10 mg/l.

The six thermal dischargers within Subsegment 24.3BA S-1 are: American Can Company, Del Monte Corporation, General Portland, Inc., Sulphur Terminals Company, Inc., Tampa Electric Company's Hookers Point Station and Winn Dixie Stores, Inc. Tables 5-3 and 5-4 provide facility descriptions and wasteloads.

24.3BA S-2 - Palm River

This subsegment includes the Palm River basin and those areas draining into the east side of McKay Bay. Archie Creek, Delaney Creek and the Palm River empty into Hillsborough and McKay Bays. Palm River and its tributary, Six-Mile Creek, are currently being turned into canals as part of the Tampa Bypass Canal Project (U. S. Army Corps of Engineers, 1974). When finally completed, the canal will extend up Six-Mile Creek and join Cow House Creek on the Hillsborough River.

Domestic Point Source. In Subsegment 24.3BA S-2 there are eight privately-owned domestic plants and no municipal plants discharging into surface waters. The total design capacity of these plants is 0.81 mgd with an approximate ADF of 0.58 mgd. Tables 5-1 and 5-2 describe the facilities and wasteloads.

Point source wasteloads being discharged into this subsegment include:

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Delaney Creek	0.007	0.23	0.5	1.16	0.35	5.549
Six Mile Creek	0.105	45.93	32.1	21.14	6.95	160.81
Palm River	0.250	23.00	25.0	26.02	15.74	149.98
McKay Bay	0.004	0.37	0.51	0.60	0.18	3.229
Hillsborough Bay	0.218	27.44	110.5	36.36	10.91	202.859
Subsegment Total	0.584	97	169	84	34	522.427

*Wasteloads are in lbs/day.

Industrial Point Sources. The four thermal dischargers within this subsegment are: Davies Can Company, Ideal Cement Company, International Minerals and Chemical Company, and TECO's F.J. Gannon Station. Compoamar Modern Dairies provides treatment for its dairy process water which is then spray irrigated, collected in an underdrain system and infrequently discharged to Delaney Creek. Other industrial dischargers include Kaiser Agricultural Company, MRI Chemicals, Inc., Nitram Chemicals, Inc., and Seaboard Coastline. Tables 5-3 and 5-4 provide more detailed information on these dischargers.

24.3BA S-3 - Cypress Creek

This subsegment includes all of the drainage area on the north side of the Hillsborough River located east of Highway 41 and west of the proposed levee of the Lower Hillsborough Flood Detention Area. Cypress Creek, the only major stream, drains the entire area and is a tributary of the Hillsborough River.

Domestic Point Sources. There are three private domestic dischargers within 24.3BA S-3 with a total design capacity of 0.020 mgd and an approximate ADF of 0.018 mgd. There are no municipal point sources. Tables 5-1 and 5-2 provide further information describing facilities and wasteloads.

Receiving Water	Flow (mgd)	BOD*	SS*	TN*	TP*	UOD*
Cypress Swamp	0.0126	2.1	-	2.1	0.6	12.6

*Wasteloads are in lbs/day.

Industrial Point Sources. There are no industrial dischargers in subsegment S-3.

24.3BA S-4 - Trout Creek

The northern and western parts of this subsegment are drained by Trout Creek, while the remaining parts are drained by Clay Gully. Both are tributaries of the Hillsborough River.

There are no domestic or industrial point sources discharging in Subsegment 24.3BA S-4.

24.3BA S-5 - Hillsborough River

This rather small subsegment includes the Hillsborough River from a point just downstream from the Hillsborough River State Park to approximately where the river crosses Highway 583 (56th Street). It also includes a drainage basin on the south, a rather small area consisting of the Cow House Creek watershed. This creek which actually appears to be the old river bed in a meander channel is the only tributary, except for a few small canals. The southern boundary runs along Highway 301. This area is in the process of undergoing substantial hydrologic modification due to the construction of the Tampa Bypass Canal. The project is intended to prevent flooding of flood-prone areas of Tampa by diverting flood waters into a series of canals which will empty into McKay Bay through the Palm River.

There are no dischargers within Subsegment 24.3BA S-5.

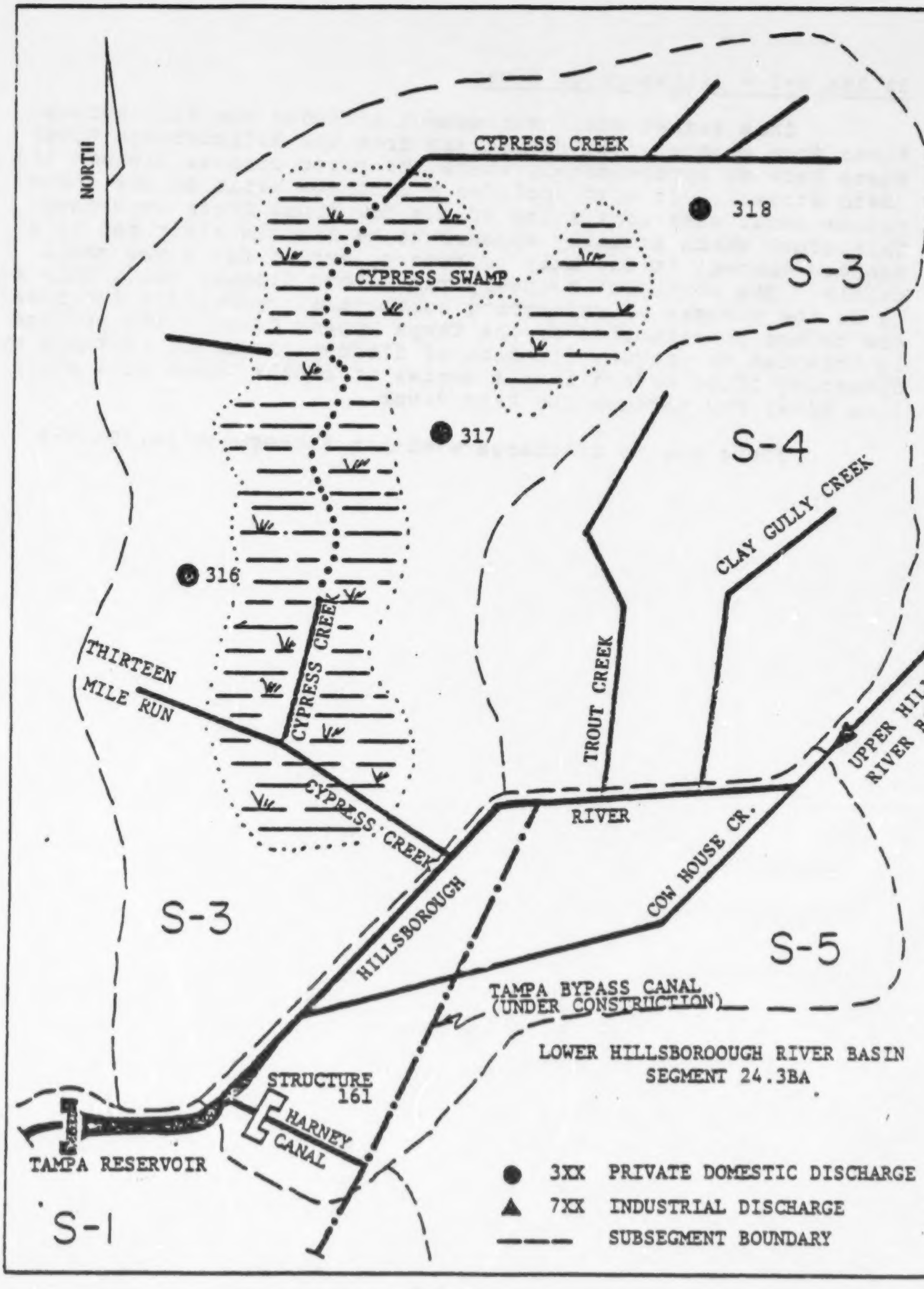
NORTH
CYPRESS CREEK
318
CYPRESS SWAMP
S-3
317
S-4
CLAY GULLY CREEK
316
TROUT CREEK
THIRTEEN
MILE RUN
CYPRESS CREEK
UPPER HILLSBOROUGH
RIVER BASIN
CYPRESS CREEK
RIVER
COW HOUSE CR.
HILLSBOROUGH
S-3
S-5
TAMPA BYPASS CANAL
(UNDER CONSTRUCTION)
LOWER HILLSBOROOUGH RIVER BASIN
SEGMENT 24.3BA
STRUCTURE
161
HARNEY
CANAL
TAMPA RESERVOIR
S-1
● 3XX PRIVATE DOMESTIC DISCHARGE
▲ 7XX INDUSTRIAL DISCHARGE
— — — SUBSEGMENT BOUNDARY

FIGURE 5-1: NORTHERN PORTION OF LOWER HILLSBOROUGH RIVER BASIN DISCHARGER SEGMENT MAP

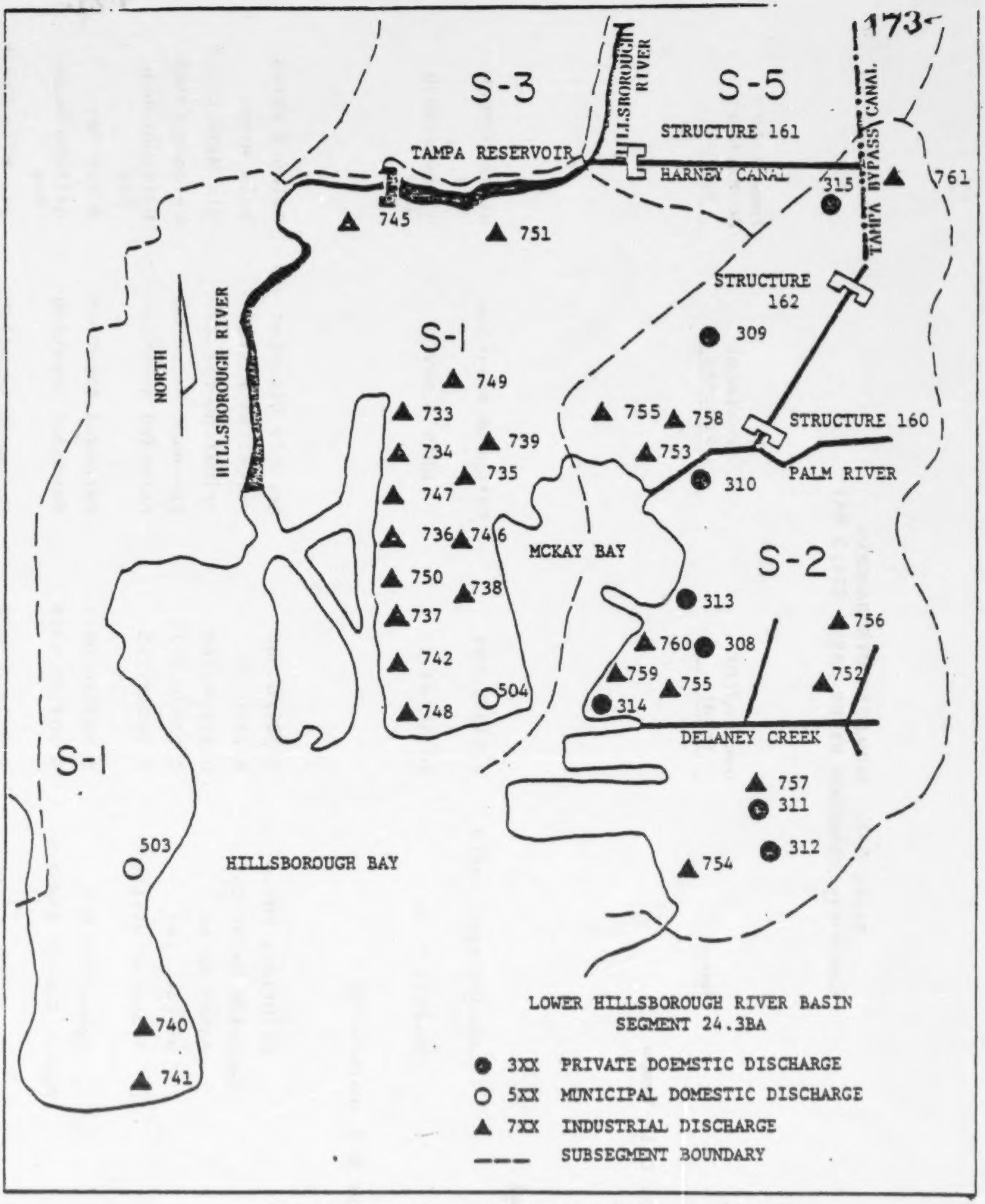
S-3
HILLSBOROUGH RIVER
S-5
STRUCTURE 161
TAMPA RESERVOIR
HARNEY CANAL
TAMPA BYPASS CANAL
315
761
745
751
STRUCTURE 162
NORTH
HILLSBOROUGH RIVER
S-1
309
749
733
755
758
STRUCTURE 160
734
739
753
735
310
PALM RIVER
747
736
746
MCKAY BAY
S-2
750
738
313
737
756
760
308
742
759
755
752
504
314
748
DELANEY CREEK
S-1
757
311
503
HILLSBOROUGH BAY
754
312
LOWER HILLSBOROUGH RIVER BASIN
SEGMENT 24.3BA
● 3XX PRIVATE DOEMSTIC DISCHARGE
○ 5XX MUNICIPAL DOMESTIC DISCHARGE
▲ 7XX INDUSTRIAL DISCHARGE
--- SUBSEGMENT BOUNDARY
740
741

FIGURE 5-2: SOUTHERN PORTION OF LOWER HILLSBOROUGH RIVER BASIN DISCHARGER SEGMENT MAP

TABLE 5-1: DOMESTIC DISCHARGERS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA)

Inventory Number	Name	Design/ADF (mgd)	Treatment Process	Immediate Receiving Waters
·Subsegment S-1--Tampa				
Private				
None				
Municipal				
503	Juanita Apartments	0.010/0.004	Extended Aeration	Hillsborough Bay
504	Hookers Point	60.00/44.72	HRAS + AWT	Hillsborough Bay
·Subsegment S-2--Palm River				
Private				
308	Chloride, Inc.	0.007/0.006	Aerobic Digestor	Delaney Creek
309	Eastside Water Co.	0.29/0.25	Trickling Filter	Palm River
310	Adamo Acres	0.271/0.100	Trickling Filter	Six Mile Creek
311	Nitram, Inc.	0.003/0.0012	Extended Aeration	Delaney Creek
312	Progress Village	0.260/0.215	Extended Aeration	Hillsborough Bay
313	Spencer's MHP	0.0035/0.0036	Extended Aeration	McKay Bay
314	TECO - Gannon Station	0.0045/0.0030	Extended Aeration	Hillsborough Bay
315	Williams Oil Co.	0.0125/0.0054	Extended Aeration	Six Mile Creek

TABLE 5-1: DOMESTIC DISCHARGERS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA) (Cont'd)

Inventory Number	Name	Design/ADF (mgd)	Treatment Process	Immediate Receiving Waters
Municipal				
None				
·Subsegment S-3--Cypress Creek				
Private				
316	Lake Padgett MHP	0.010/-	Extended Aeration	Cypress Swamp
317	Quail Hollow	0.005/0.006	Extended Aeration	Cypress Swamp
318	Stuckey's	0.005/0.002	Extended Aeration	Cypress Swamp
Municipal				
None				
·Subsegment S-4--Trout Creek				
None				
·Subsegment S-5--Hillsborough River				
None				

TABLE 5-2: DOMESTIC WASTELOADS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-1						
Private						
None						
Municipal						
503	0.0038	0.0956	0.1329	0.1575	0.0508	.85
504	44.72	2101	1056	1020	1252	6182
Basin Total	44.7238	2101	1056	1020	1252	6183
Subsegment S-2						
Private						
308	0.0058	0.2336	0.5321	0.9674	0.2902	4.687
309	0.2500	23.000	25.000	26.0208	15.7418	149.9836
310	0.1000	45.8900	32.1000	19.2400	6.6803	152.203
311	0.0012	0.000	0.000	0.2002	0.0600	.901
312	0.2150	27.000	110.000	35.862	10.759	199.989
313	0.0036	0.3703	0.5104	0.6005	0.1801	3.232
314	0.0030	0.4440	0.4860	0.5004	0.1501	2.887
315	0.0054	0.0432	--	0.9007	0.2702	4.115
Municipal						
None						
Basin Total	0.5840	96.9811	168.6285	84.292	34.1317	517.9976

TABLE 5-2: DOMESTIC WASTELOADS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA) (Cont'd)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				
		BOD	SS	TN	TP	UOD
Subsegment S-3						
Private						
316	0.0100	2.000	--	1.668	0.5004	10.366
317	0.006	0.000	0.0000	0.1001	0.0300	.45045
318	0.0020	0.1000	--	0.3336	0.1001	1.6442
Municipal						
None						
Basin Total	0.0126	2.1000	0.0000	2.1017	0.6305	12.46065

TABLE 5-3: INDUSTRIAL DISCHARGERS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
Subsegment S-1				
733	General Portland, Inc.	Bulk Cement Terminal	-/0.01	Hillsborough Bay
734	" "	" "	-/0.07	" "
735	American Can Co.	Can Fabrication	-/0.27	" "
736	American Oil Co.	Terminal	-/0.0008	" "
737	American Petrofina Co.	"	-/-	" "
738	City Service Oil Co.	"	-/0.0001	" "
739	Del Monte Corp.	Food Processor	-/0.121	McKay Bay
740	MacDill Defense Fuel Facility	Terminal	-/-	Hillsborough Bay
741	MacDill Fighter Support Facil.	--	-/-	" "
742	Murphy Oil Co.	Terminal	-/-	" "
743	Philips Petroleum Co.	"	-/-	" "
745	City of Tampa - Water Treatment Plant	Alum. Sludge Ponds	-/-	Hillsborough Rvr.
746	TECO - Hooker's Point Sta.	Power Plant	-/225.5	Hillsborough Bay
747	Texaco, Inc.	Terminal	-/-	" "
748	S. T. Tringali Co.	Seafood Processing	-/0.0015	" "
749	Union Carbide Corp.	Bulk Facility	-/-	" "
750	Union Oil Co.	Terminal	0.087/-	" "
751	Winn Dixie Stores	Warehouse	-/0.033	Hillsborough Rvr.

TABLE 5-3 : INDUSTRIAL DISCHARGERS
LOWER HILLSBOROUGH RIVER BASIN (24.3BA) (Cont'd)

Inventory Number	Name	Facility Activity	Design/ADF (mgd)	Immediate Receiving Waters
Subsegment S-2				
752	Campoamor Modern Dairy	Feedlot (Runoff)	-/-	Hillsborough Bay
753	Davies Can Co.	Can Fabrication	-/0.0086	Palm River
754	Ideal Cement Co.	Bulk Cement Terminal	-/-	Hillsborough Bay
755	IMC Corp.	Bulk Materials Terminal	-/0.722	" "
756	Kaiser Chemical Co.	Chemical Mfg.	-/0.0278	Six Mile Creek
757	Nitram Chemical Co.	" "	-/0.3804	Hillsborough Bay
758	Seaboard Coastline R.R.	Rail/Yard	0.325/0.464	Palm River
759	TECO - Gannon Station	Power Plant	-/1280	Hillsborough Bay
760	W.R. Grace & Co.	Chemical Mfg.	-/1.44	" "
761	MRI Corp.	" "	-/-	Six Mile Creek

Subsegment S-3

None

Subsegment S-4

None

Subsegment S-5

None

TABLE 5-4 : INDUSTRIAL WASTELOADS
LOWER HILLSBOROUGH RIVER BASIN (24.3 BA)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				Other Parameters
		BOD	SS	TN	TP	
Subsegment S-1						
733	0.01	--	--	--	--	pH, T
734	0.07	--	--	--	--	pH
735	0.27	--	--	--	--	pH, T
736	0.0008	--	--	--	--	pH, GO
738	0.0001	--	--	--	--	GO
739	0.012	0.47	--	--	--	pH, T
746.003	225.5	--	--	--	--	T
748	0.0015	--	0.0113	--	--	--
750	0.087	--	--	--	--	OG, pH, Pb, Tu
751	0.033	--	--	--	--	T, pH
S-1	226.00	0.47	0.0113	--	--	
Subsegment S-2						
753	0.0086	--	--	--	--	pH, T
755	0.722	--	14.7	--	--	pH
756	0.028	--	0.2	4	--	pH
757	0.3804	--	19.0	144	--	pH, T
758.001	0.464	30.94	11.6	--	--	pH, GO, COD
758.002	0.229	279	168	--	--	pH, GO, COD
759.002	303	--	--	--	--	T, FC, RC
759.004	0.066	--	9.96	--	--	GO, Cu, Fe
759.005	5.41	--	3113.2	--	--	pH, GO, Cu, Fe, As, Cd, Cr, Pb, Hg, Ni, Se, Zn
S-2	310.3	307.9	3337	148	--	

TABLE 5-4: INDUSTRIAL WASTELOADS
LOWER HILLSBOROUGH RIVER BASIN (24.3)(Cont'd)

Inventory Number	Flow (mgd)	Parameter (lbs/day)				Other Parameters
		BOD	SS	TN	TP	
Subsegment S-3						
None						
Subsegment S-4						
None						
Subsegment S-5						
None						
Basin Total	536.3	310.4	3337	148	--	

SECTION 6

SUMMARY

Information contained in Sections 2 through 5 describe the present point source discharges within the National Urban Runoff Program Study Area. Data have been displayed identifying private domestic, municipal domestic, and industrial discharges. Through compiling this information by stream segment, total loads attributable to subsegments and segments can be obtained. Furthermore, total loads can be developed representing point source loads within the free-flowing streams, directly into the estuarial system, and directly into the bay system. These totals will provide the necessary delineation of point source loads for further comparison with total loads during storm events.

Wasteload Summaries

Wasteload information displayed in previous sections of the report have been summarized in Tables 6-1, 6-2, 6-3, 6-4 and 6-5. These tables provide an overview of the individual sources of point source wasteloads for each discharge category within each subsegment, segment, and the total study area. Combining these summaries with the previously displayed figures, total loads within given stream reaches and basin inputs can be evaluated with respect to point source impacts.

Tables 6-1 and 6-2 display the respective number of permitted discharge points and actual dischargers responsible for those discharges. These tabulations identify the relationship between the 157 permitted discharges operated by the 81 dischargers within the study area. Tables 6-3 and 6-4 expand the actual number of dischargers into the respective wasteloads for domestic point sources and industrial point sources. Each presentation displays the total flow, BOD, suspended solids, total N, and total P within each subsegment, segment, and the total study area. Finally, Table 6-5 combines these two sets of information into a total domestic and industrial point source load from the 81 dischargers contained within the entire study area. This total load represents the entire point source input to the hydrologic resource within the study area.

Water Resource Wasteload Summary

Beyond the individual subsegment load identifications, a summary has been prepared describing the point source load within the river segment upstream of the estuarial system, the point source load discharged into the estuarial river segments, and the point source loads discharged directly into the bay system. Figure 6-1 schematically depicts these sources of load. Data summarizing loads in the Bullfrog Creek and North Ruskin portions of the Little Manatee River Basin, Alafia River system, the Hillsborough River system, and the Palm River system are displayed in Table 6-6.

The first loads were calculated from the stream flow and quality measured at the identified location. These locations were selected as representative of the most downstream location which is least affected by the estuarial system. Data presented for the mouth of the river systems represent actual quality measurements. The flow values which are listed are only gross estimates of quantity and must not be used for mass loading calculations. The bay and estuarial discharges represent an aggregation of point sources that discharge directly into the estuarial transition zone of each water course system and direct discharges to the Hillsborough Bay system.

The data summary in Table 6-6 provides the necessary information required to address the impact of the individual rivers as point source loads upon the bay and the estuarial segments of the water resource. Furthermore, summarizing the existing point source wasteload information at the point where tidal fluctuations impact water quantity and quality, data evaluations regarding the impact of non-point sources can be readily delineated.

Recognizing that the Hillsborough and Alafia Rivers have seasonal variations in both quantity and quality, Table 6-7 has been prepared to delineate wet season/dry season wasteload variations. As before, actual water quality information for selected stations has been combined with published USGS mean monthly discharge values to estimate seasonal wasteloads at various points in the study area.

Information displayed in Table 6-7 is based upon water quality data since 1972. Water quality data for the six-year period (1973-1978) and corresponding USGS quantity data was utilized to calculate the wasteloads. This time span has been relatively dry with the cumulative departure from the average annual precipitation of 48.80 inches amounting to 52.26 inches for this period, or approximately one equivalent year of precipitation. Long-term stream flow data indicates higher mean annual discharge values for the Alafia and Hillsborough Rivers than experienced during any year in the 1973-1978 period. The flows and wasteloads in Table 6-7 are based on recent data in order that comparisons can be made with recently collected water quality data. In developing wasteloads limitation, consideration will be given to conditions where rainfall and river flows are higher than those in the 1972-1978 period.

As previously stated, the values summarized in this section are for permitted point sources and represent a gross estimate of loads of specific parameters that are regulated by existing permits for continuous discharges. These values, by necessity, do not include intermittent discharges which are permitted, or continuous or intermittent point sources which are not permitted.

It is also important, when reviewing these values, to remember that existing permits regulate specific parameters at different types of industry. All pollutants are not monitored at every discharge. Therefore, the reported pollutant loads represent only the regulated loads due to permitted discharges. They do not purport to represent the total point source loads in the study area--only the permitted and regulated loads.

TABLE 6-1: SUMMARY OF PERMITTED DISCHARGE POINTS

		Domestic			
		Private	Municipal	Industrial	Total
Little Manatee Rvr. Basin 24.1 AA	S-2	2	0	0	2
	S-6	3	0	9	12
	Basin	5	0	9	14
Alafia River Basin 24.2 AA	S-1	1	0	13	14
	S-X	0	1	58	59
	Basin	1	1	71	73
Upper Hillsborough Rvr. Basin 24.3 AA	S-1	0	1	1	2
	S-2	1	0	3	4
	S-3	0	0	2	2
	S-4	0	0	0	0
	Basin	1	1	6	8
Lower Hillsborough Rvr. Basin 24.3 BA	S-1	0	2	33	35
	S-2	8	0	16	24
	S-3	3	0	0	3
	S-4	0	0	0	0
	S-5	0	0	0	0
	Basin	11	2	49	62
Study Area Total		18	4	135	157

TABLE 6-2: SUMMARY OF PERMITTED DISCHARGERS

		Domestic			
		Private	Municipal	Industrial	Total
Little Manatee Rvr. Basin	S-2	2	0	0	2
24.1 AA	S-6	3	0	3	6
	Basin	5	0	3	8
Alafia River Basin	S-1	1	0	2	3
24.2 AA	S-X	0	1	22	23
	Basin	1	1	24	26
Upper Hillsborough Rvr.Basin	S-1	0	1	1	2
24.3 AA	S-2	1	0	3	4
	S-3	0	0	1	1
	S-4	0	0	0	0
	Basin	1	1	5	7
Lower Hillsborough Rvr.Basin	S-1	0	2	19	21
24.3 BA	S-2	8	0	8	16
	S-3	3	0	0	3
	S-4	0	0	0	0
	S-5	0	0	0	0
	Basin	11	2	27	40
Study Area Total		18	4	59	81

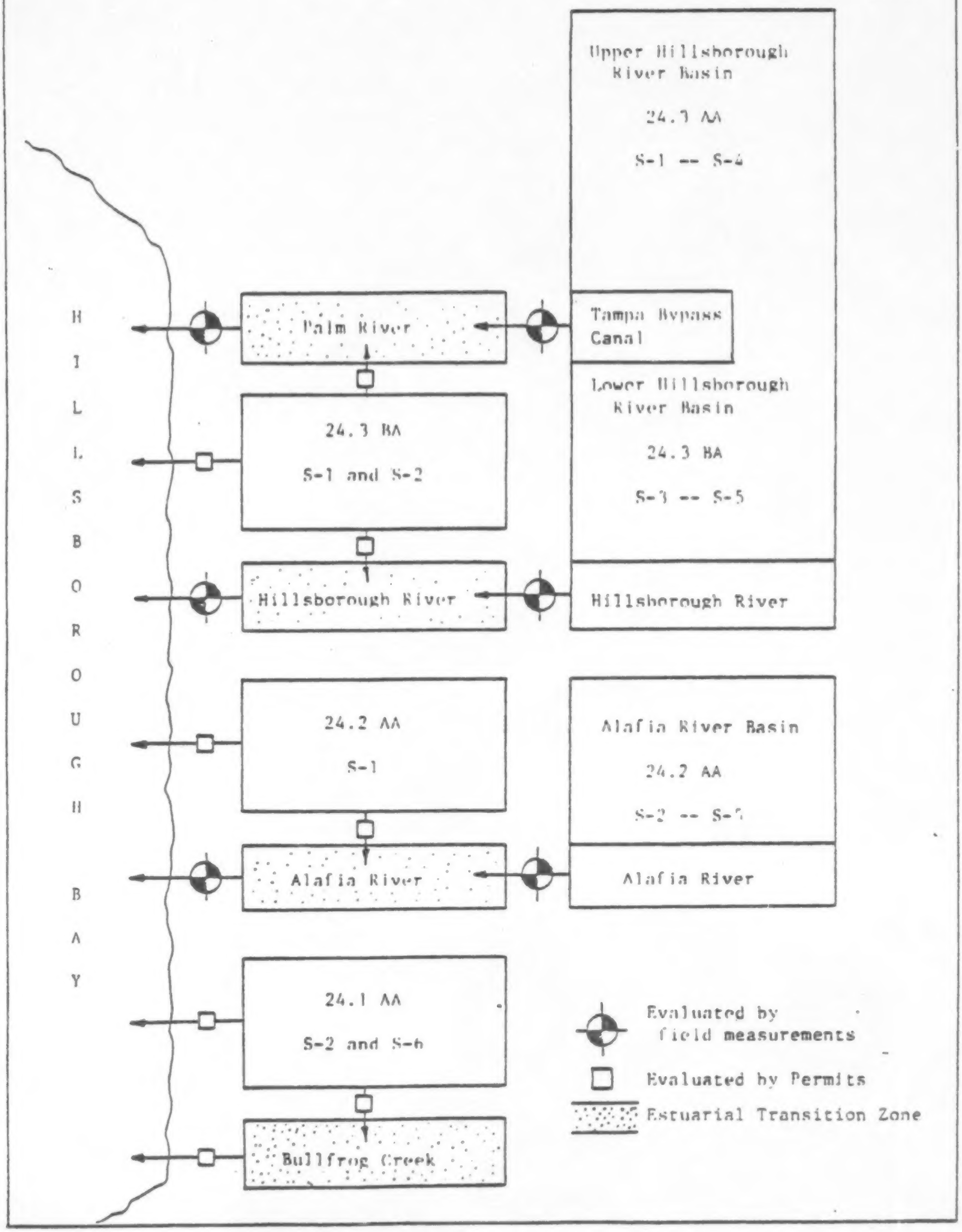
Upper Hillsborough River Basin
24.3 AA
S-1 -- S-4
Tampa Bypass Canal
Palm River
Lower Hillsborough River Basin
24.3 BA
S-3 -- S-5
24.3 BA
S-1 and S-2
Hillsborough River
Hillsborough River
24.2 AA
S-1
Alafia River Basin
24.2 AA
S-2 -- S-5
Alafia River
Alafia River
24.1 AA
S-2 and S-6
Bullfrog Creek
H I L L S B O R O U G H B A Y
Evaluated by field measurements
Evaluated by Permits
Estuarial Transition Zone

FIGURE 6-1: SCHEMATIC WASTELOAD SUMMARY
HILLSBOROUGH BAY HYDROLOGIC SYSTEM

TABLE 6-3: SUMMARY OF DOMESTIC POINT SOURCE WASTELOADS

		Flow (mgd)	Wasteload in lbs/day			
			BOD	SS	TN	TP
24.1 AA	S-2	0.0124	0.98	1.08	2.07	0.63
	S-6	0.0151	0.99	1.49	2.51	0.76
	All	0.03	2	3	5	1
24.2 AA	S-1	0.0130	0.01	0.00	0.03	0.01
	S-X	0.26	22	--	43.37	13.01
	All	0.27	22	0	43	13
24.3 AA	S-1	3.400	141.78	396.98	226.85	17.01
	S-2	0.030	5	0	5	1.50
	S-3	0	0	0	0	0
	S-4	0	0	0	0	0
	All	3.43	147	397	232	19
24.3 BA	S-1	44.7238	2101	1056	1020	1252
	S-2	0.5840	97.0	168.63	84.29	34.13
	S-3	0.0126	2.10	0.00	2.10	0.63
	S-4	--	--	--	--	--
	S-5	--	--	--	--	--
	All	45.3204	2200	1225	1106	1287
Study Area Total		49.05	2371	1625	1386	1320

TABLE 6-4: SUMMARY OF INDUSTRIAL POINT SOURCE WASTELOADS

		Flow (mgd)	Wasteload in lbs/day			
			BOD	SS	TN	TP
24.1 AA	S-2	0	0	0	0	0
	S-6	825.95	0	0	0	0
	All	825.95	0	0	0	0
24.2 AA	S-1	66.30	0	1684	0	373
	S-X	79.62	0	5267	0.3	2187
	All	145.92	0	6951	0	2560
24.3 AA	S-1	0.36	30	22	0	0
	S-2	0.81	67	229	0	0
	S-3	2.56	0	451	0	207
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	3.73	97	702	0	207
24.3 BA	S-1	226.00	0	0	0	0
	S-2	310.30	310	3337	148	0
	S-3	0	0	0	0	0
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	536.3	310	3337	148	0
Study Area Total		1511.90	407	10,990	148	2767

TABLE 6-5: SUMMARY OF DOMESTIC AND INDUSTRIAL POINT SOURCE WASTELOADS

		Flow (mgd)	Wasteload in lbs/day			
			BOD	SS	TN	TP
24.1 AA	S-2	0.012	0.98	1.08	2.07	0.63
	S-6	825.965	0.99	1.49	2.51	0.76
	All	825.977	2	3	5	1
24.2 AA	S-1	66.313	0.01	1684	0.03	373.01
	S-X	79.880	22.00	5267	43.67	2200
	All	146.193	22	6951	44	2573
24.3 AA	S-1	3.76	171.78	418.98	226.85	17.01
	S-2	0.84	72.00	229	5.00	1.50
	S-3	2.560	0	451	0	207
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	7.160	244	1099	232	226
24.3 BA	S-1	270.724	2101	1056	1020	1252
	S-2	310.884	406.98	3506	232.29	34.13
	S-3	0.013	2.10	0	2.10	0.63
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	581.621	2510	4562	1254	1287
Study Area Total		1560.951	2778	12615	1535	4087

TABLE 6-6: WASTELOAD SUMMARY

HILLSBOROUGH BAY HYDROLOGIC SYSTEM

River Basin	FLOW (mgd)	Parameter (lbs/day)			
		BOD_5	SS	TKN	TP
Little Manatee					
Upstream Load	--	--	--	--	--
River Outlet	--	--	--	--	--
Estuarial Load	0.0124	0.98	1.08	2.07	0.63
Bay Discharge	825.97	0.99	1.49	2.51	0.76
Alafia					
Upstream Load (Station 114)	293	4,304	12,741	954	9,219
River Outlet	329	(2.3 mg/l)	(46.0 mg/l)	(0.36 mg/l)	(1.41 mg/l
Estuarial Load	--	--	--	--	--
Bay Discharge	66.31	0.01	1684	0.03	373
Hillsborough					
Upstream Load (22nd St.Bridge)	383	3,198	18,474	959	991
River Outlet (Hillsborough)	434	(2.75 mg/l)	(31.05 mg/l)	(0.34 mg/l)	(0.88 mg/l
Upstream Load (Palm River @ Structure 160)	114	3,132	22,747	619	777
River Outlet (Palm River)	140	(3.56 mg/l)	(22.84 mg/l)	(0.37 mg/l)	(0.88 mg/l
Estuarial Load (Palm River)	1.05	379	237	45.3	22.4
Bay Discharge	581.8	2,211	4,436	1,230	2,134

TABLE 6.7: SEASONAL WASTELOAD SUMMARY

HILLSBOROUGH BAY HYDROLOGIC SYSTEM

	SOURCE	FLOW (mgd)	Pollutant Load (lbs/day)				
			BOD$_5$	SS		TN	TP
1.	Hookers Point AWT Plant(1)	44.7	2,100	1,060	695	1,020	1,250
		53.5	3,800	1,840	925	1,300	2,500
2.	Hillsborough River(2,3) Entering the Reservoir	432.4	4,190	13,500	548	889	1,940
		115.2	1,470	5,300	290	606	505
3.	Hillsborough River(2,4) Reservoir Releases to Lower River	351.2	4,690	28,000	606	1,270	1,430
		103.7	1,210	4,290	185	387	329
4.	Sulphur Springs Discharge(2,5)	24.7	--	--	--	501	344
		21.4	--	--	--	434	299
5.	Alafia River Entering(2,6) the Estuarial Transition Zone	310.1	3,880	15,600	1,650	3,960	8,680
		169	2,160	12,800	484	1,160	4,710
6.	Permitted Point Sources(7,8) Discharging Directly to Hillsborough River Reservoir	0	0	0	0	0	0
7.	Permitted Point Sources(7,9) Discharging Directly to Lower Hillsborough River	0	0	0	0	0	0
8.	Permitted Point Sources(7) Discharging Directly to Upper Hillsborough Bay	53.3	2,510	4,560	1,250	--	2,190
9.	Permitted Point Sources(7) Discharging Directly to Lower Hillsborough Bay	16.2	2	1,690	5	--	374

TABLE 6.7: SEASONAL WASTELOAD SUMMARY

HILLSBOROUGH BAY HYDROLOGIC SYSTEM (Cont'd)

NOTES:

(1) Data for AWT Plant is based on FDER Monthly Operating Reports for October 1979-September 1980 during which the plant has been AWT operational. Top number represents daily mean value for the 12-month period while bottom number represents the maximum value for each pollutant during the same period.

(2) Top number is average wet month, bottom number is average dry month, unless otherwise noted. Values based on observed data collected on a monthly basis.

(3) Evaluated at Fowler Avenue Bridge.

(4) Evaluated at dam, not adjusted for diversion.

(5) Evaluated on flow records and water quality observed in closest wells located in the same geologic unit.

(6) Evaluated at Bell Shoals Bridge.

(7) Point source loads are permitted for continuous discharge without regard for seasonal variation. Flows associated with power plant once through cooling have been subtracted.

(8) The only permitted point source to the reservoir is a thermal discharge of cooling water.

(9) The City of Tampa Water Treatment Plant is the only permitted point source in the river below the dam and only permitted for intermittent discharge from the alum sludge ponds.

LIST OF ABBREVIATIONS

cfs - cubic feet per second

mgd - million gallons per day

ADF - average daily flow

BOD - biochemical oxygen demand

SS - suspended solids

TN - total nitrogen

TP - total phosphorous

pH - pH

Temp - temperature

Ra - radium 226

F - flouride

Zn - zinc

FC - free chlorine

CF - fecal coliform

RC - residual chlorine

Cr - chromium

GO - grease and oil

Tu - turbidity

Pb - lead

VS - volatile solids

COD - chemical oxygen demand

Cu - copper

Fe - iron

LIST OF ABBREVIATIONS (Cont'd)

As - arsenic

Cd - cadmium

Hg - mercury

Ni - nickel

Se - selenium

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SECTION 1

INTRODUCTION

In order to perform an evaluation of the water quality impacts related to different sources, each individual source must be quantified in terms of flow (rate and volume) and load (pounds/time). The principal sources contributing inputs to the Tampa Study Area receiving waters are: rivers (Hillsborough River and Alafia River), point source discharges (municipal and private), and non-point sources (urban runoff). Each of these sources has been individually evaluated in terms of wet weather and dry weather inputs to various river segments and to the Hillsborough Bay system.

Actual flow and load values determined from field measurements were utilized where available. Predictive equations developed by the USGS were utilized to generate non-point source contributions based upon the five-year urban study evaluation. Each Sections 2, 3 and 4 of this summary present the assumptions, data sources, and results utilized to generate each component pollutant source. Section 5 presents the interpretations associated with the cumulative load data generated from each source.

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SECTION 2

RIVERS AS POLLUTION SOURCES

River Loads

The two principal rivers that discharge to the Hillsborough Bay System are the Hillsborough and Alafia Rivers. These water courses can either be viewed as conduits which are receiving water bodies while passing through land masses or as pollution sources that contribute to the receiving waters of the Hillsborough Bay system. The latter view will be utilized in this section.

The quantification of loads associated with these two pollution sources is based on monitored flow and observed water quality. The USGS monitors flow at numerous points in the Hillsborough and Alafia River basins. The daily flow values published by the USGS on an annual basis have been either used directly or manipulated to arrive at daily and monthly flow values for the Alafia River at Bell Shoals Road Bridge, the Hillsborough River at Fowler Avenue Bridge, and the Hillsborough River at the Tampa Waterworks Dam. These daily values were analyzed for mean monthly values for the 48 months of Water Years 1976-1979 inclusively (October 1975-September 1979). The mean monthly values were then analyzed in terms of wet and dry months to determine mean values which can be used for describing flow for a typical wet or dry month.

The water quality of these rivers is sampled on a monthly basis by the Hillsborough County Environmental Protection Commission which reports monthly and mean annual concentrations for various monitoring points based on the results of monthly grab samples. Water quality information collected for the Alafia River at the Bell Shoals Road Bridge, and the Hillsborough River at the Fowler Avenue Bridge and just downstream of the Tampa Waterworks dam was used to evaluate monthly loads for selected pollutants. Individual monthly loads were calculated for each wet month and each dry month. These loads were then analyzed for mean monthly values which were used to describe the river loads for typical wet and dry months. These loads are presented in Table 2-1.

The Hillsborough County Environmental Protection Commission has, for recent years, used the Orion Probe method to determine Kjeldahl Nitrogen (TKN) concentrations in water samples. In approximately March, 1980, the laboratory switched to a new method of determining TKN values, the Technicon Auto-Analyzer method, which is the method used by the City of Tampa at the Hookers Point AWT Plant. Individuals reviewing the TKN data

TABLE 2-1: TYPICAL WET AND DRY MONTH LOAD VALUES AND STUDY AREA RIVER CONTRIBUTIONS

	MONTHLY RIVER LOADS		
	Hillsborough River at Fowler Avenue	Hillsborough River at Tampa Dam	Alafia River at Bell Shoals Bridge
Wet Month			
Monthly Volume (acre-feet)	40,400	32,800	29,100
Average Flow Rate (MGD)	432	351	312
Biochemical Oxygen Demand (lbs)	127,000	143,000	118,000
Suspended Solids (lbs)	410,000	851,000	473,000
Total Kjeldahl Nitrogen (lbs)[1]	16,700	18,500	50,100
Total Kneldahl Nitrogen (lbs)[2]	167,000	185,000	501,000
Total Nitrogen (lbs)[1]	34,800	38,500	120,000
Total Nitrogen (lbs)[2]	185,000	205,000	571,000
Total Phosphorus (lbs)	58,800	44,400	264,000
Dry Month			
Monthly Volume (acre-feet)	10,700	9,860	15,700
Average Flow Rate (MGD)	115	104	169
Biochemical Oxygen Demand (lbs)	44,700	36,700	65,600
Suspended Solids (lbs)	161,000	130,000	389,000
Total Kjeldahl Nitrogen (lbs)[1]	8,820	5,630	14,700
Total Kjeldahl Nitrogen (lbs)[2]	88,200	56,300	147,000
Total Nitrogen (lbs)[1]	18,400	11,700	35,400
Total Nitrogen (lbs)[2]	97,800	62,400	168,000
Total Phosphorus (lbs)	15,400	10,000	143,000

---

[1] Based on TKN determination by Orion Probe technique

[2] Based on TKN determination by Technicon Auto-Analyzer technique

noticed a significant change in TKN values which coincided with the change in analytical methods. The laboratory began to split samples and analyze for TKN using both the Orion Probe and the Technicon Auto-Analyzer methods to see if there was a consistent difference in TKN values. A recent finding (December 17, 1980) by laboratory staff is that there is approximately an order of magnitude of difference in the TKN values of the split samples such that values determined by the Technicon Auto-Analyzer method are approximately TEN TIMES HIGHER than the values determined by the Orion Probe Method.

Total Nitrogen values reported for the rivers are based on relationships between the various nitrogen species because all of the nitrogen species are analyzed in every monthly sample. Analysis of the various nitrogen species in the Hillsborough and Alafia Rivers results in a relationship such that:

Total Nitrogen = (Factor) x (Total Kjeldahl Nitrogen)

where the factor value is as follows:

	Alafia River	Hillsborough River
TKN determined by Technicon	1.1404	1.1088
TKN determined by Orion Probe	2.404	2.088

Examination of Table 2-1 reveals two sets of TKN and Total Nitrogen values which are identified by the method which was used to determine the TKN, and hence, Total Nitrogen values. Both values are given in order that comparisons can be drawn with values in subsequent sections of this report which are determined by the Technicon Auto-Analyzer method. The original report for Task I.3B and Task I.3C contain only the TKN and TN values determined by the Orion Probe Method because the difference in methods was not known at the time of their prepatation. This report has been revised to include both sets of values.

However, it must be noted that this finding of procedural difference and the corresponding results in TKN and TN values has a substantial impact on the interpretation of the rivers' role in the whole pollutant contribution picture. Section 5 of this report deals with interpretation of the relative contribution of the rivers, the point sources and the non-point source to the Hillsborough Bay system. The tables which deal with this interpretation have been revised to include both sets of TN values in order that each individual component load may be compared on the basis of the same analytical procedure for nitrogen. The text of Section 5 was not revised due to time constraints and refers to comparisons based on different analytical procedures for TN. The text, with regard to all other individual component parameters, is correct and unaffected by the difference in analytical techniques used for nitrogen analysis.

Sulphur Springs Loads

One aspect of the Lower Hillsborough River which is appropriate to examine in this section is the contribution of Sulphur Springs to the river. The springs are located below the Waterworks Dam and contribute flow to the Lower Hillsborough River under normal operation but spring flow is pumped into the reservoir pool during periods of low flow to augment the impounded river water for the City's raw water supply.

Water quality of the Sulphur Springs discharge is of particular interest due to its highly variable nature. Normally, the discharge is typical of other springs in the Tampa Bay Area in terms of typical groundwater quality. However, the discharge changes drastically during and after significant rainfall events by becomming turbid, colored and having significantly higher coliform bacteria counts. A dye tracer study was conducted in 1958 to examine the local belief that the sink holes, which are numerous and characteristic of the area immediately north of the springs, were directly connected to Sulphur Springs by solution fissures or some other karst phenomena. The study documented that the sink holes were interconnected with each other and also connected to Sulphur Springs.

Water quality of the Sulphur Springs is well documented in terms of bacterial and water treatment paramenters but little information exists regarding the concentration of BOD, SS, TN or TP in the discharge. For lack of data, no estimate of either BOD or SS has been prepared. Monthly estimates of TN and TP concentrations are based on groundwater concentrations analyzed in the two closest wells in the same geologic unit which are monitored by USGS. The discharge of Sulphur Springs is monitored by the USGS and the monthly flow can be combined with the TN and TP concentrations to estimate a typical wet and dry month load. This estimated load must be viewed as very conservative because it represents the best possible case, unadulterated groundwater, and does not take into consideration the stormwater which enters the karst system via the numerous sink holes and mixes with the groundwater prior to discharge at Sulphur Springs.

	TYPICAL MONTHLY LOADS	
	Wet Month	Dry Month
Mean Monthly Flow Rate (cfs)	38.3	33.2
Mean Monthly Flow Volume (acre-feet)	2,310	2,000
Total Nitrogen (lbs)	501	434
Total Phosphorus (lbs)	344	299

SECTION 3

POINT SOURCES

Study Area

The study area for the point source inventory includes the Alafia, Lower Hillsborough, and Upper Hillsborough River Basins as well as a portion of the Little Manatee River Basin. These basins comprise approximately 1170 square miles or 39 percent of the greater 3000 square mile Tampa Basin. This area might accurately be described as the Hillsborough Bay Basin. Figure 3-1 depicts the generalized boundary of the study area.

The portion of the Little Manatee River Basin which is included in the Hillsborough Bay Basin lies entirely in southern Hillsborough County. The areas of concern are the coastal areas immediately adjacent to Hillsborough Bay and Bullfrog Creek which receives runoff and baseflow from the coastal lowlands. The total area of this portion of the Little Manatee River Basin is approximately 63 square miles.

The Alafia River is located in Hillsborough and Polk Counties, and drains approximately 460 square miles. The headwaters flow from Polk County westward through coastal lowlands 24 miles prior to entering the south end of Hillsborough Bay. Land use categories in the Alafia River basin include agriculture (36%), range (17%), and barren land (12%). The relatively high percentage of barren land reflects the fact that the river flows through an area of extensive phosphate mining and rock processing operations. The Alafia river drains approximately 420 square miles and discharges directly into Hillsborough Bay.

Originating in the Green Swamp area in Pasco County, the Hillsborough River flows southwesterly for approximately 55 miles through coastal lowlands emptying into the northern end of Hillsborough Bay. The Hillsborough River provides the potable water supply for Tampa, Florida. The drinking water reservoir formed on the river is located approximately 10 miles upstream of the discharge to Hillsborough Bay. Land use in the upper Hillsborough River Basin (headwaters to Clay Gully Creek) includes a relatively large percentage of urban (13%), agriculture (52%) and range-land (17%). Agriculture (40%), urban (22%) and range-land (17%) are the primary land use categories in the lower Hillsborough River Basin (Clay Gully Creek to Hillsborough Bay).

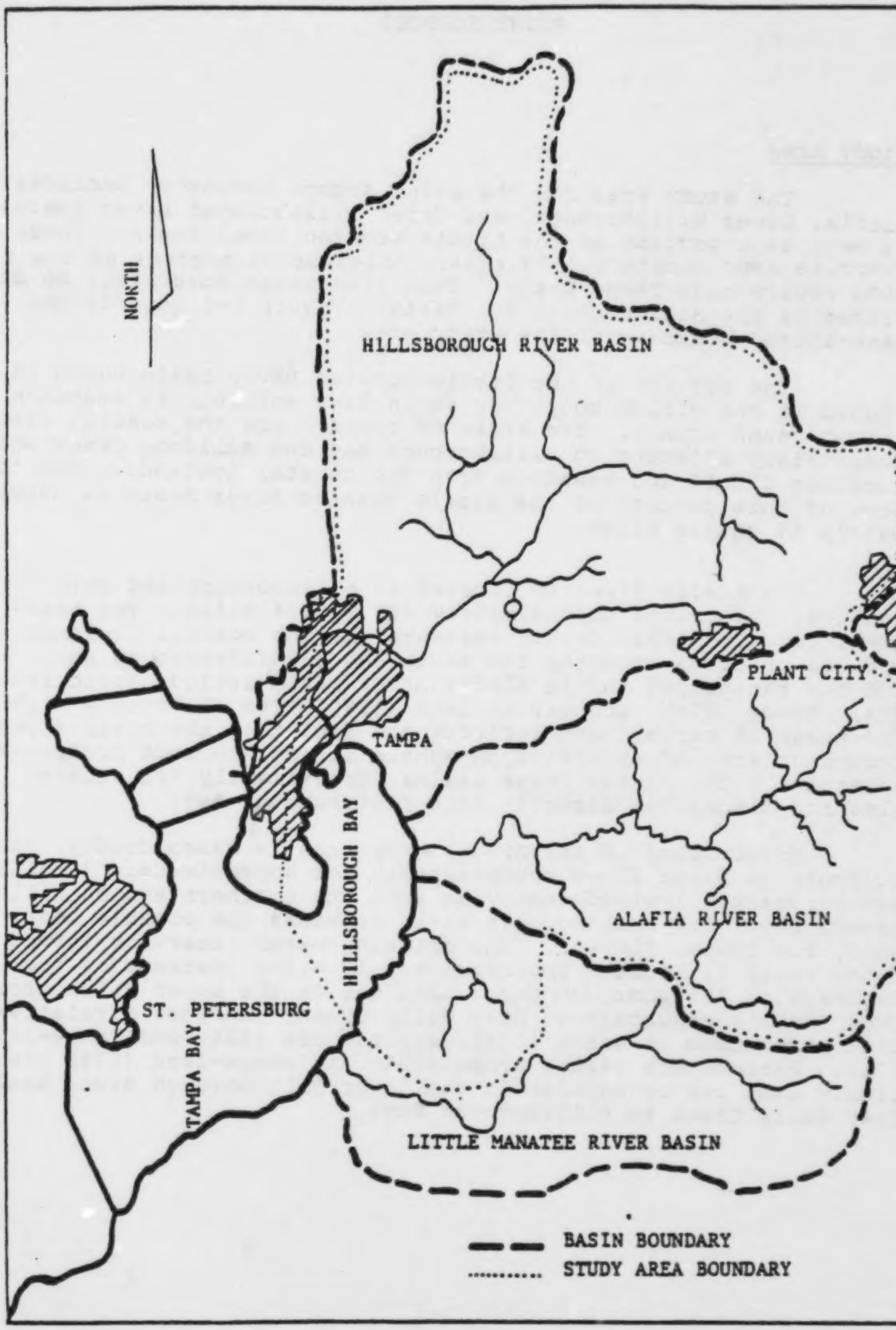
NORTH
HILLSBOROUGH RIVER BASIN
PLANT CITY
LAKELAND
TAMPA
HILLSBOROUGH BAY
ALAFIA RIVER BASIN
ST. PETERSBURG
TAMPA BAY
LITTLE MANATEE RIVER BASIN
BASIN BOUNDARY
STUDY AREA BOUNDARY

FIGURE 3-1: DRAINAGE BASIN BOUNDARIES

R

The study area has been divided into segments by the Florida Department of Environmental Regulation (FDER) corresponding to natural drainage basins and subdivided into subsegments which correspond to the smaller drainage areas within individual basins. FDER hydrologic units which comprise the study area include:

24.1AA - Little Manatee River Basin

S-2 - Bullfrog Creek
S-6 - North Ruskin

24.2AA - Alafia River Basin

S-1 - Alafia River West
S-2 - Turkey Creek
S-3 - Alafia River South
S-4 - Alafia River North
S-5 - Alafia River East

24.3AA - Upper Hillsborough River Basin

S-1 - Thonotosassa
S-2 - Blackwater Creek
S-3 - Zephyrhills
S-4 - New River

24.3BA - Lower Hillsborough River Basin

S-1 - Tampa
S-2 - Palm River
S-3 - Cypress Creek
S-4 - Trout Creek
S-5 - Hillsborough River

Methodology and Assumptions

Data Acquisition. Point source discharge permits issued by the U. S. Environmental Protection Agency (EPA) and Florida Department of Environmental Regulation (FDER) for both domestic and industrial discharges to waters which are tributary to the Hillsborough River/Hillsborough Bay system have been reviewed. All EPA National Pollutant Discharge Elimination System permits as well as FDER construction/operation permits on file at the FDER District Office in Tampa, Florida, have been inventoried and summarized. This information has been catalogued by stream segment and is contained in the domestic/industrial point source appendix.

Information contained in the permit applications on file at FDER's offices has been entered on the point source discharger summary as "design" conditions. Information contained in FDER compliance monitoring reports and the periodic monitoring reports of the Hillsborough County Environmental Protection Commission (HCEPC) has been entered as "actual" conditions. Permitted point source dischargers within the study area have been organized by the segment and subsegment in which they are located. This method of organization facilitates finding individual dischargers and determining the point source wasteloads contributed to the receiving waters within each subsegment, segment, and ultimately to Hillsborough Bay.

Data Limitations. Three important factors to be considered when using the points source inventory are: (1) the inventory contains only those point source which are known to State and local agencies and hold valid discharge permits; (2) the discharges are only regulated for specific pollutants by specific industries and that a given industry may be discharging quantities of a pollutant of interest in this study but may not be required to report its concentration and, therefore, is not accounted for in the total basin load; and, (3) that intermittent discharges can not be quantified and may have a substantial impact on total basin loads. Use of the values in this document must include the understanding that this inventory includes evaluation of known quantifiable point sources but does not purport to evaluate all point sources in the three drainage basins.

Domestic Dischargers. The domestic dischargers for each basin are individually described in terms of inventory number, name, design capacity, average daily flow (ADF), treatment process and immediate receiving waters. Additionally, estimates of BOD, SS, TN, TP and UOD are given in lbs/day for all dischargers. Daily BOD and SS loads were estimated using the reported ADF flow rate and average BOD and SS effluent concentrations.

During the Tampa Bay 208 Study, the Tampa Bay Regional Planning Council (TBRPC) contacted various Federal, State and local pollution control agencies in order to establish numerical default values for TN, TKN, and TP for secondary wastewater treatment plants. In an effort to utilize a value which would be consistent and realistic for the Tampa Bay Region, TBRPC elected to use an average value of 20.0 mg/l for determining the TN wasteloads for secondary plants. Also, in reviewing the various values for TP, a value of 6.0 mg/l was established as the average concentration in a seconary effluent and was utilized in the wasteload calculations. Daily loads for TN

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[a] Tampa Bay Regional Planning Council, Point Sources Inventories for the Tampa Bay Region, St. Petersburg, February, 1977.

and TP were generally calculated using these default values and reported ADF. In addition to the four small facilities reporting TN and TP values, wasteloads attributable to the City of Tampa's Hookers Point AWT Plant were based upon operating reports. Discussions and correspondence with the City[b] resulted in the use of 2.72 mg/l TN and 5.54 mg/l TP with a 12-month ADF of 44.7 MGD.

FDER calculates wasteloads in terms of ultimate oxygen demand (UOD) which is the amount of oxygen required for complete stabilization of remaining carbonaceous and nitrogenous matter in the wastewater effluent. This includes both the amount of oxygen required for decomposition of organic matter (expressed as carbonaceous biochemical oxygen demand) and nitrification which is the oxidation of ammonia and organic nitrogen to nitrate nitrogen (expressed as nitrogenous biochemical oxygen demand). The UOD of the various domestic sources was calculated by using the following relationship: UOD = 1.43(BOD)+4.57(TKN), where all units are expressed in lbs/day. Generally, default values of 20 mg/l TN and TKN utilized, however, actual monthly average values were used for the City of Tampa's Hookers Point AWT Plant.(b)

Industrial Dischargers. The industrial dischargers for each basin are individually described in terms of inventory number, name, principal industrial activities, design capacity, average daily flow, and immediate receiving waters. Additionally, estimates of BOD, SS, TN, TP, and other parameters specifically listed on the permit are given in lbs/day for all dischargers. Estimates of UOD were not prepared for industrial dischargers due to the complex nature of industrial effluents and lack of adequate effluent monitoring information which would be required for such an estimate.

Wasteload Summaries

Wasteload information contained in the Point Source Inventory has been summarized in Tables 3-1 and 3-2. These tables provide an overview of the individual sources of point source wasteloads for each discharge category within each subsegment, segment, and the total study area. Through combining these summaries, total loads within given stream reaches and basin inputs can be evaluated with respect to point source impacts.

(b) Monthly Operating Report Summaries, Department of Sanitary Sewers, City of Tampa, September 26, 1980.

TABLE 3-1: SUMMARY OF PERMITTED DISCHARGERS

		Domestic			
		Private	Municipal	Industrial	Tota
Little Manatee Rvr. Basin 24.1 AA	S-2	2	0	0	2
	S-6	3	0	3	6
	Basin	5	0	3	8
Alafia River Basin 24.2 AA	S-1	1	0	2	3
	S-X	0	1	22	23
	Basin	1	1	24	26
Upper Hillsborough Rvr.Basin 24.3 AA	S-1	0	1	1	2
	S-2	1	0	3	4
	S-3	0	0	1	1
	S-4	0	0	0	0
	Basin	1	1	5	7
Lower Hillsborough Rvr.Basin 24.3 BA	S-1	0	2	19	21
	S-2	8	0	8	16
	S-3	3	0	0	3
	S-4	0	0	0	0
	S-5	0	0	0	0
	Basin	11	2	27	40
Study Area Total		18	4	59	81

TABLE 3-2: SUMMARY OF DOMESTIC AND INDUSTRIAL POINT SOURCE WASTELOADS

		Flow (mgd)	Wasteload in lbs/day			
			BOD	SS	TN	TP
24.1 AA	S-2	0.012	0.98	1.08	2.07	0.63
	S-6	825.965	0.99	1.49	2.51	0.76
	All	825.977	2	3	5	1
24.2 AA	S-1	66.313	0.01	1684	0.03	373.01
	S-X	79.880	22.00	5267	43.67	2200
	All	146.193	22	6951	44	2573
24.3 AA	S-1	3.76	171.78	418.98	226.85	17.01
	S-2	0.84	72.00	229	5.00	1.50
	S-3	2.560	0	451	0	207
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	7.160	244	1099	232	226
24.3 BA	S-1	270.724	2101	1056	1020	1252
	S-2	310.884	406.98	3506	232.29	34.13
	S-3	0.013	2.10	0	2.10	0.63
	S-4	0	0	0	0	0
	S-5	0	0	0	0	0
	All	581.621	2510	4562	1254	1287
Study Area Total		1560.951	2778	12615	1535	4087

Table 3-1 displays the actual number of permitted dischargers within the study area. Table 3-2 expands the actual number of dischargers into the combined wasteloads due to domestic point sources and industrial point sources. This table contains the total flow, BOD, suspended solids, total N, and total P within each subsegment, segment, and the total study area. This total load represents the entire permitted point source input to the hydrologic resource within the study area as can be determined from available permit application and compliance monitoring information.

Specific summaries of single point sources and geographic groups of point sources are useful in evaluating point source loads entering various stream segments. Table 3-3 contains the very significant single point sources and four geographically grouped aggregations of point sources which are pertinent in evaluating the cumulative effect of various load components entering local receiving waters.

As previously state, the values summarized in this section are for permitted point sources and represent a gross estimate of specific parameter loads that are regulated by existing permits for continuous discharges. These values, by necessity, do not include intermittent discharges which are permitted, or continuous or intermittent point sources which are not permitted.

In addition, existing permits regulate specific parameters at different types of industry. All pollutants are not monitored at every discharge. Therefore, the reported pollutant loads represent only the regulated loads due to permitted discharges. They do not purport to represent the total point source loads in the study area--only the permitted and regulated loads.

TABLE 3-3: SUMMARY OF SIGNIFICANT SINGLE POINT SOURCES AND GEOGRAPHIC GROUPS OF POINT SOURCES

	Hookers Point[1] AWT Plant	Sulphur[2] Springs	Reservoir	Permitted Point[3] Sources Discharging Directly to		
				Lower River	Upper Bay	Lower Bay
Monthly Volume (acre-ft.)	4,170 4,980	2,310 2,000	0	0	4,980	1,520
Average Flow Rate (MGD)	44.7 53.3	24.7 21.4	0	0	53.3	16.2
Biochemical Oxygen Demand (lbs)	63,900 116,000	- -	0	0	76,300	61
Suspended Solids (lbs)	32,200 56,000	- -	0	0	139,000	51,400
Total Nitrogen (lbs)	31,000 39,500	15,200 13,200	0	0	38,000	152
Total Phosphorus (lbs)	38,000 76,000	10,500 9,100	0	0	66,600	11,400

Notes: (1) Top number represents the monthly average for October 1979 - September 1979, second number represents maximum monthly value during the same 12-month period.

(2) First number represents a typical wet month, second number represents a typical dry month.

(3) These point sources are permitted for continuous discharge without seasonal variation and specifically exclude power plant thermal discharges.

SECTION 4

NON-POINT SOURCES

Introduction

The urbanized portions of Tampa, Temple Terrace, and unicorporated Hillsborough County which drain to the Hillsborough River below the Fowler Avenue bridge, or drain directly to Hillsborough Bay comprise the study area for the purposes of urban runoff characterization. This area has been divided into 13 drainage areas for purposes of analyzing runoff flows and loads (Figure 4-1). These individual flows and loads were then aggregated to the level of three major drainage areas which can be combined to estimate the characteristics of the runoff generated by the entire Tampa Urban Area.

Hydrologic Response Analysis

The urban hydrology data base developed by the United States Geological Survey (USGS) during their 1975-1980 Tampa Bay Urban Area Study was examined utilizing multiple regression methodology to determine predictive load models for base flow, storm peak flow, and runoff volume. A statistical analysis system developed at North Carolina State University (SAS 76) was used by the USGS to perform stepwise multiple regression and associated calculations. The stepwise regression procedure was used in the analysis of the urban hydrographs for their nine urban basins. This procedure examines the contribution made by each basin characteristic and meterological factor at every step. The three predictive models for determining base flow, storm peak flow, and storm runoff volumes were develped by the USGS.

The predictive models developed by the USGS were applied to the urban basins for two months of representative precipitation events occurring in the wet and dry seasons. The hydrologic responses predicted by the models were anlyzed to determine representative response characteristics for a "typical" wet and dry month and with the results summarized in Table 4-1.

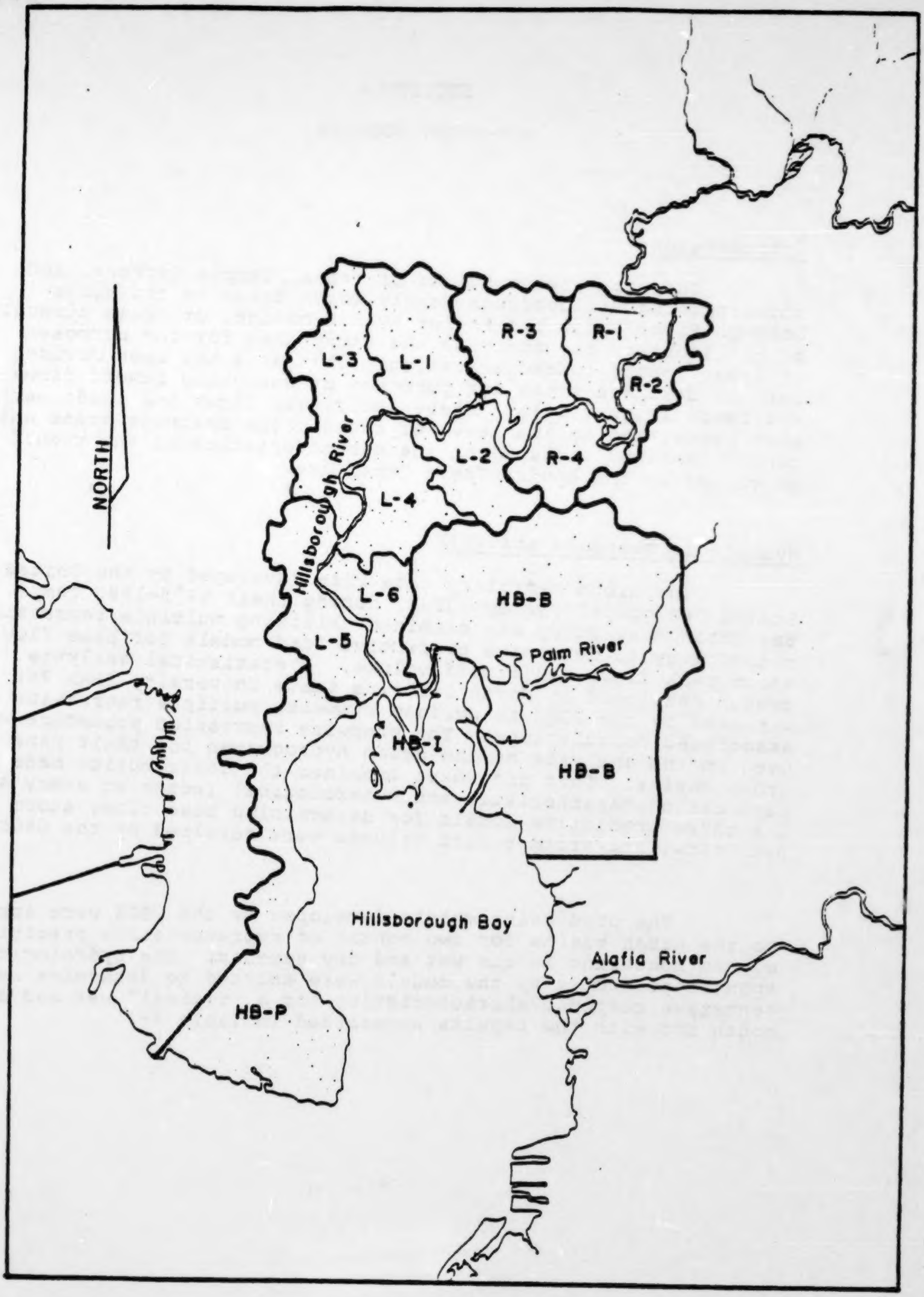
L-3
L-1
R-3
R-1
R-2
L-2
R-4
L-4
L-6
L-5
NORTH
Hillsborough River
HB-B
Palm River
HB-I
HB-B
Hillsborough Bay
Alafia River
HB-P

FIGURE 4-1: URBAN DRAINAGE BASINS

Urban Runoff Pollutant Load Responses

Water quality data collected by the USGS during storm events and base flow conditions in 9 urban basins (Tampa Bay Urban Study) were analyzed by the USGS to determine relationships between: (1) recorded physical basin characteristics and meterological factors; and (2) observed storm loads and base flow loads for select pollutants.

As with the hydrologic responses, multiple regression modeling was used to analyze this water quality information. Based on the selected pollutant load data, predictive models generated by the USGS from the regression analysis.

These pollutant load equations were applied to each of the thirteen urban basins. Utilizing appropriate physical, cultural and environmental factor values, each day within the two representative months for both wet and dry seasons was evaluated. The individual basin responses to single storms were analyzed and aggregated to the level of the three major drainage basins and the entire Tampa Urban Area.

Base flow water quality information contained within the urban data base was analyzed for mean concentration values for the same six pollutants. These mean values were combined with the predicted base flows from each of the thirteen urban basins to predict base flow pollutant loads.

Suspended solids data were not collected by the USGS in the Tampa Bay Urban Study. Based upon studies conducted in Houston, Texas, a relationship for suspended solids loads based upon storm runoff values was used to evaluate storm loads. Base flow loads were developed from mean suspended solids concentrations in local streams as monitored by the Hillsborough County Environmental Protection Commission.

Tables 4-2 contains the typical monthly values for cumulative monthly flows and selected pollutant loads for the wet and dry seasons with values for each drainage area and the total area. The individual loads have been compared to the total load, in the form of percent of total load.

TABLE 4-1: TYPICAL WET AND DRY SEASON URBAN RUNOFF HYDROLOGIC RESPONSES FOR THE MAJOR DRAINAGE AREAS IN THE TAMPA URBAN AREA

	Wet Month	Dry Month
Directly to Hillsborough River Reservoir:		
. Daily Base Flow (cfs)	14.5	8.9
. Storm Peak Flow (cfs)	46.7	47.3
. Storm Runoff Volume Per Event (acre-ft.)	2.8	3.0
. Cumulative Monthly Runoff (acre-ft.)	908	545
Directly to Lower Hillsborough River:		
. Daily Base Flow (cfs)	32.4	19.8
. Storm Peak Flow (cfs)	109.4	110.5
. Storm Runoff Volume Per Event (acre-ft.)	16.0	17.3
. Cumulative Monthly Runoff (acre-ft.)	2150	1240
Directly to Hillsborough Bay:		
. Daily Base Flow (cfs)	30.4	28.4
. Storm Peak Flow (cfs)	137.9	139.6
. Storm Runoff Volume Per Event (acre-ft.)	6.7	7.5
. Cumulative Monthly Runoff (acre-ft.)	1920	1730

TABLE 4-2: TYPICAL WET AND DRY MONTH LOAD VALUES MAJOR DRAINAGE AREAS

	TYPICAL MONTHLY LOADS						Total Urban Area Non-Point
	Reservoir		Lower River		Bay Discharge		
	Load	Percent	Load	Percent	Load	Percent	Load
Wet Months							
. V (acre-ft)	908	18	2,150	43	1,920	39	4,980
. BOD (lb)	23,000	22	44,900	43	37,100	35	105,000
. SS (lb)	64,500	16	203,000	49	145,000	35	413,000
. TN (lb)	5,330	18	12,000	40	12,600	42	29,900
. TP (lb)	2,160	20	2,790	26	5,820	54	10,800
Dry Months							
. V (acre-ft)	545	16	1,240	35	1,730	49	3,520
. BOD (lb)	10,300	19	21,500	40	22,300	41	54,100
. SS (lb)	33,000	16	87,200	43	82,900	41	203,000
. TN (lb)	3,370	19	7,160	39	7,620	42	18,200
. TP (lb)	692	19	1,130	30	1,870	51	3,680

SECTION 5

INTERPRETATIONS OF CUMULATIVE LOADS

Hydrologic and pollution load responses to given precipitation events, utilizing a variety of techniques, have been prepared and analyzed in the three preceeding sections of this report. This section will interpret the generated typical wet and dry month values for flow and selected pollutant loads through the use of a simplified flow model and a more detailed flow model which has four distinct portions.

Simplified Conceptual Model

Initially, a very simple conceptual model composed of a river component, an urban runoff component and a permitted point source component can be utilized to evaluate the aggregated quantity and quality responses of the entire Tampa Urban Area. The river component represents a combination of the inputs of the Hillsborough River into the reservoir as evaluated at Fowler Avenue, the Alafia River discharge to Hillsborough Bay evaluated at Bell Shoals Bridge including the Lithia Springs discharge, and the Sulphur Springs discharge to the Hillsborough River below the Dam. The urban runoff component represents the total urban quantity and quality responses of the thirteen urban basins. The point source component represents all the permitted point sources that discharge either directly or indirectly to Hillsborough Bay. In this conceptual model, the receiving water is Hillsborough Bay and specifically excludes Bullfrog Creek and any agricultural runoff or runoff originating in residential areas not included in the previously defined Tampa Urban Area. Table 5-1 presents a schematic representation of this conceptual model and summarizes the typical wet and dry month values for total monthly volume (V), as well as the estimated monthly biochemical oxygen demand (BOD), suspended solids (SS), total nitrogen (TN), and total phosphorus (TP) loads.

The comparison that this simple model affords is the net load of the individual components on the receiving waters. Hydraulically, the rivers component has by far the largest contribution with better than 85 percent of the total flow for both wet and dry typical months. However, the rivers have relatively smaller roles when pollutant loads are considered.

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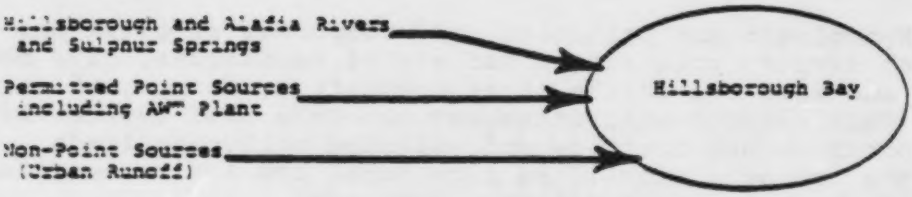
TABLE 5-1: Typical Wet and Dry Month Load Values for the Simplified Conceptual Model


Hillsborough and Alafia Rivers and Sulphur Springs
Permitted Point Sources including AWT Plant
Non-Point Sources (Urban Runoff)
Hillsborough Bay

	INDIVIDUAL COMPONENTS			
	River Inputs	Point Sources	Non-Point Sources	Combined
Wet Month				
Monthly Volume (acre-feet)	71,800 (96)	6,490 (8)	4,980 (6)	83,300
Average Flow Rate (MGD)	769 (85)	70 (9)	53 (6)	892
Biochemical Oxygen Demand (lbs)	245,000 (57)	76,400 (18)	105,000 (25)	426,000
Suspended Solids (lbs)	883,000 (60)	190,000 (13)	410,000 (28)	1,480,000
Total Nitrogen (lbs)	155,000[1] (69)	38,200[3] (17)	30,000[4] (13)	223,000
Total Nitrogen (lbs)	754,000[2] (92)	38,200[3] (5)	30,000[4] (3)	822,000
Total Phosphorus (lbs)	323,000 (78)	78,000 (19)	10,800 (3)	412,000
Dry Month				
Monthly Volume (acre-feet)	28,400 (74)	6,490 (17)	3,520 (9)	38,400
Average Flow Rate (MGD)	305 (74)	70 (17)	38 (9)	413
Biochemical Oxygen Demand (lbs)	110,000 (46)	76,400 (32)	54,200 (23)	241,000
Suspended Solids (lbs)	550,000 (58)	190,000 (20)	203,000 (22)	943,000
Total Nitrogen (lbs)	54,200[2] (49)	38,200[3] (35)	18,200[4] (16)	111,000
Total Nitrogen (lbs)	266,000[1] (82)	38,200[3] (12)	18,200[4] (6)	322,000
Total Phosphorus (lbs)	159,000 (66)	78,000 (32)	3,690 (2)	241,000

KEY: 908 = Monthly Load in units specified
(2) = Relative contribution as a percentage of the combined value

NOTES:
1. Nitrogen load based on Technicon Auto-Analyzer TKN method
2. Nitrogen load based on Orion Probe TKN method
3. Nitrogen load based on NPDES and/or FDER Discharge Permit
4. Nitrogen load based on USGS multiple regression analysis equation

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Point source discharges comprise only 8 percent of the total flow during the wet months yet contribute 13-19 percent of the total pollutant load. This trend is similar during the dry season when point sources comprise only 17 percent of the hydraulic load yet contain 20-35 percent of the total pollutants. Point sources have significant impact relative to their flow component for all of the pollutants. This statement is particularly true for BOD, TN, and TP.

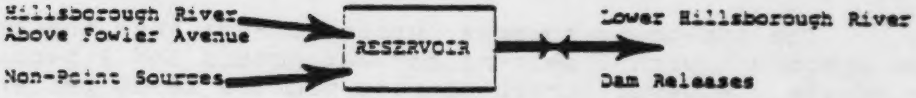
The non-point sources (urban runoff) have the smallest flow component with 6 percent for wet months and 9 percent for dry months. However, these sources produce 13-28 percent of the total BOD, SS and TN components. Also significant is the fact that the BOD and SS percentage load components are greater than four times the percentage flow component; further emphasizing the significance of these pollution sources.

Detailed Conceptual Model

The use of a more detailed conceptual model allows the examination of flow volume and pollutant load impacts on more discrete reaches of the river and bay system. Themodel used for this purpose has four distinct sections: (1) the reservoir - Hillsborough River between Fowler Avenue and the City dam; (2) the lower river - Hillsborough River between the dam and the mouth; (3) the upper bay - the northern portion of the Hillsborough/McKay Bay system; and, (4) the entire bay - the entire Hillsborough/McKay Bay system. This model allows the upper examination of the interrelationships of the segments.

Reservoir Segment - This segment receives inflow from the Hillsborough River (evaluated at Fowler Avenue) and four urban basins. Flow leaves this segment when released at the dam into the lower river segment or withdrawn slightly upstream of the dam through the City water treatment plant intake. Additionally, the reservoir has a fixed storage capacity which is monitored to provide water supply and control downstream releases. This aspect of the segment explains the discontinuity in flow volumes and pollutant loads entering the lower river. Table 5-2 contains a schematic representation of this reach and summarizes typical wet and dry season loads.

TABLE 5-2: TYPICAL WET AND DRY MONTH LOAD VALUES DETAILED CONCEPTUAL MODEL UPPER HILLSBOROUGH RIVER



	INDIVIDUAL COMPONENTS			
	River	Point Sources	Non-Point Sources	Combined
Wet Month				
Monthly Volume (acre-feet)	40,400 (98)	0	908 (2)	41,000
erage Flow Rate (MGD)	432 (98)	0	10 (2)	442
Biochemical Oxygen Demand (lbs)	127,000 (85)	0	23,000 (15)	150,000
Suspended Solids (lbs)	410,000 (86)	0	64,500 (14)	475,000
Total Nitrogen (lbs)	34,800[1] (87)	0	5,330[2] (13)	40,200
Total Nitrogen (lbs)	185,000[3] (97)	0	5,330[2] (3)	190,000
Total Phosphorus (lbs)	58,300 (96)	0	2,160 (4%)	61,000
Dry Month				
Monthly Volume (acre-feet)	10,700 (95)	0	545 (5)	11,300
Average Flow Rate (MGD)	115 (95)	0	6 (5)	121
Biochemical Oxygen Demand (lbs)	44,700 (81)	0	10,300 (19)	55,000
Suspended Solids (lbs)	161,000 (83)	0	33,000 (17)	194,000
Total Nitrogen (lbs)	18,400[1] (85)	0	3,370[2] (15)	21,800
Total Nitrogen (lbs)	97,800[3] (97)	0	3,370[2] (3)	101,000
Total Phosphorus (lbs)	15,400 (96)	0	692 (4)	16,100

KEY: 908 = Monthly load in units specified
(2) = Relative contribution in percentage of combined value

NOTES:
1. Nitrogen load based on Orion Probe TKN method
2. Nitrogen load based on USGS multiple regression analysis
3. Nitrogen load based on Technicon Auto-Analyzer TKN method

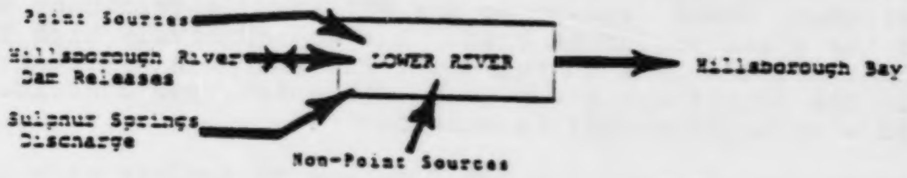
For this river segment, the urban runoff load as a percentage of the total segment load is less than predicted for the entire study area with the simplified model. With no point source discharges, the river flow volume constitutes 95 percent or more of the total flow, regardless of season. However, the urban runoff pollutant loads (exception for TP) are a significant component of the total pollutant load. Due to relatively high TP background concentrations in the Upper Hillsborough River, reflected in the percentage river loads component, the contribution associated with urban runoff is masked.

Urban runoff loads for BOD, SS, and TN exhibit more significant impacts during the dry season than during the wet season with 27, 21, and 15 percent higher relative load component values, respectively. Clearly, urban runoff loads to the Hillsborough River Reservoir are significant during either wet or dry months. The combined flows, urban runoff and river inputs, provide variations in reservoir storage volume, provide raw water supply to the City of Tampa Water Treatment Plant, or are discharged over the dam to the Lower Hillsborough River.

Lower River Segment - The lower river segment receives inflow from the regulated dam releases and six urban basins. Flow is attenuated only by minimal in-reach storage with discharge directly to Hillsborough Bay. In addition to the dam release and urban runoff, the Lower River receives discharge from Sulphur Springs, a natural spring which is believed to be connected with the extensive system of sinkholes and natural limestone hydraulic conduit system in the upper portion of the aquifer. The hydraulic discontinuity caused by the dam and reservoir requires the utilization of estimated dam release volumes for wet and dry months. Table 5-3 schematically depicts the lower river segment and summarizes the wet and dry season loads.

Based upon four years of data, dam releases represent the largest flow and pollutant load in this segment during both wet and dry months. The Sulphur Springs discharge was evaluated based on USGS measurements and observed water quality in adjacent wells. Interestingly, the springs constitute 6-15 percent of the typical monthly flow yet account for 3 percent or less of the total pollutant loads.

TABLE 5-3: TYPICAL WET AND DRY MONTH LOAD VALUES DETAILED CONCEPTUAL MODEL - LOWER HILLSBOROUGH RIVER



	INDIVIDUAL COMPONENTS				
	Dam Releases	Sulphur Springs	Point Sources	Non-Point Sources	Combined
Wet Month					
Monthly Volume (acre-feet)	32,800 (88)	2,310 (6)	0	2,150 (6)	37,300
erage Flow Rate (MGD)	351 (88)	25 (6)	0	23 (6)	399
Biochemical Oxygen Demand (lbs)	143,000 (76)	0	0	44,900 (24)	188,000
Suspended Solids (lbs)	851,000 (81)	0	0	203,000 (19)	1,054,000
Total Nitrogen (lbs)	38,500[1] (75)	501[2] (1)	0	12,000[3] (24)	51,000
Total Nitrogen (lbs)	205,000[4] (94)	501[2] (0)	0	12,000[3] (6)	218,000
Total Phosphorus (lbs)	44,400 (93)	344 (1)	0	2,790 (6)	47,500
Dry Month					
Monthly Volume (acre-feet)	9,680 (75)	2,000 (15)	0	1,240 (10)	12,900
Average Flow Rate (MGD)	104 (75)	21 (15)	0	13 (10)	138
Biochemical Oxygen Demand (lbs)	36,700 (63)	0	0	21,500 (37)	58,200
Suspended Solids (lbs)	130,000 (60)	0	0	87,200 (40)	217,000
Total Nitrogen (lbs)	11,700[1] (61)	434[2] (2)	0	7,160[3] (37)	19,300
Total Nitrogen (lbs)	62,400[4] (89)	434[2] (1)	0	7,160[3] (10)	70,000
Total Phosphorus (lbs)	10,000 (87)	299 (3)	0	1,120 (10)	11,400

KEY: 908 = Monthly load in units specified
(2) = Relative contribution in percentage of combined value

NOTES:
1. Nitrogen load based on Orion Probe TKN method
2. Nitrogen load based on USGS Groundwater Monitoring Network
3. Nitrogen load based on USGS multiple regression analysis
4. Nitrogen load based on Technicon Auto-Analyzer TKN method

In the absence of point sources, the impact of the urban runoff is very pronounced. Non-point sources account for only 6 percent of the flow during the wet months yet constitute 19-24 percent of the individual pollutant loads. During the dry months, 10 percent of the flow is attributable to urban runoff with corresponding pollutant loads ranging from 37 to 40 percent. This trend indicates that the pollutant load, as a percentage of the total load, tends to be four times the relative contribution of the runoff flow in the segment. The exception to this prediction is TP which tends to be lower for urban runoff due to natural background levels.

Northern Hillsborough Bay Segment - This segment of the model includes the norther portion of Hillsborough Bay, including all of McKay Bay, and receives flow from the Lower Hillsborough River, Palm River, Delaney Creek and three urban basins which discharge directly to the Bay. Additionally, a large number of point sources are located around Hillsborough Bay which discharge directly to the Bay. Included in these point sources is the Tampa AWT Plant which is treated as a separate component. Table 5-4 schematically depicts the Northern Bay segment and summarizes the wet and dry season loads.

Examination of the flows and loads attribtued to the individual components of this segment indicates the extensive amount and diversity of loads. As with all previous segments, the Hillsborough River presents the largest single flow and pollutant load component. However, the flows and loads attributed to the river represent the attenuated river flows and loads (controlled by the dam) and urban runoff flows and loads generated in drainage areas which discharge to the reservoir and Lower Hillsborough River.

The Tampa AWT Facility is the largest single point source, in terms of pollutant loads, in the Tampa Urban Area and is treated as a separate component. The plant has been in full operation as an AWT Facility for approximately 12 months and the loads presented are the average of the last 12 months (October 19, 1979-September 19, 1980). Due to this limited number of monthly values, accurate wet and dry month characteristics could not be developed. During the wet months, the plant contributes only 9 percent of the total flow entering northern Hillsborough Bay while supplying 21 percent of the total estimated BOD. The plant is accomplishing appropriate solids removal and discharges only 2 percent of the total SS load. With regard to nutrients, (TN and TP), the plant effluent constitutes approximately 30 percent of the total estimated nutrient load entering the bay.

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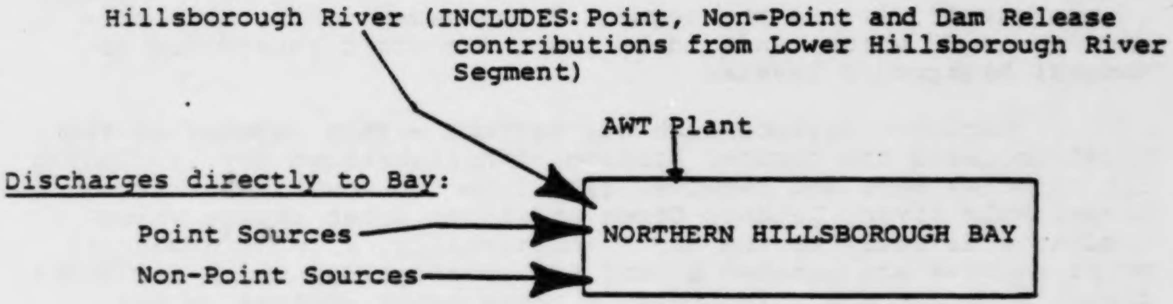
TABLE 5-4: TYPICAL WET AND DRY MONTH LOAD VALUES DETAILED CONCEPTUAL MODEL - NORTHERN HILLSBOROUGH BAY


Hillsborough River (INCLUDES: Point, Non-Point and Dam Release contributions from Lower Hillsborough River Segment)
AWT Plant
Discharges directly to Bay:
Point Sources
Non-Point Sources
NORTHERN HILLSBOROUGH BAY

	INDIVIDUAL COMPONENTS				
			Direct Bay Discharge		
Wet Month	AWT Plant	Hills-borough River	Point Sources	Non-Point Sources	Combi
Monthly Volume (acre-feet)	4,170 (9)	37,300 (84)	810 (2)	1,920 (4)	44,20
Average Flow Rate (MGD)	45 (9)	399 (84)	8 (2)	21 (4)	4
Biochemical Oxygen Demand (lbs)	63,900 (21)	188,000 (62)	12,400 (4)	37,100 (12)	301,0 0
Suspended Solids (lbs)	32,100 (2)	1,054,000 (79)	107,000 (8)	145,000 (11)	1,340,00
Total Nitrogen (lbs)	31,000 (31)	51,000 (50)	7,000 (7)	12,600 (12)	102,0
Total Phosphorus (lbs)	38,100 (32)	47,500 (40)	28,600 (24)	5,820 (5)	120,000
Dry Month					
Monthly Volume (acre-feet)	4,170 (21)	12,900 (66)	810 (4)	1,730 (9)	19,6
Average Flow Rate (MGD)	45 (21)	138 (66)	8 (4)	19 (9)	21
Biochemical Oxygen Demand (lbs)	63,900 (41)	58,200 (37)	12,400 (8)	22,300 (14)	157,0
Suspended Solids (lbs)	32,100 (7)	217,000 (49)	107,000 (24)	82,900 (19)	439,0 0
Total Nitrogen (lbs)	31,000 (48)	19,300 (30)	7,000 (11)	7,620 (12)	64,90
Total Phosphorus (lbs)	38,100 (48)	11,400 (14)	28,600 (36)	1,870 (2)	80,0

NOTE: 908 - First number equals monthly value.
(2) - Second number equals percentage of combined value.

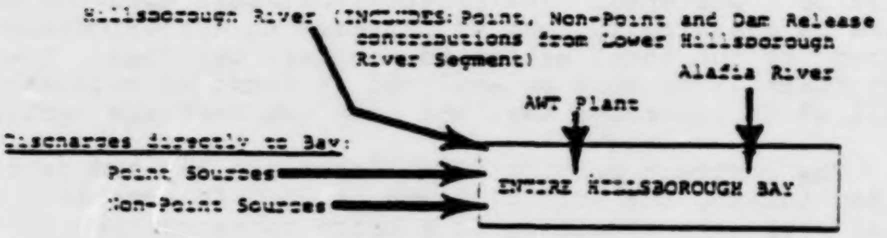
Drying dry months, the AWT plant flows constitute 21 percent of the total flow; approximately double the relative flow of the wet months. A similar increase is seen in BOD (21 to 41 percent) with a slightly higher relatively increase in SS (2 to 7 percent). The relative nutrient loads do not increase as drastically, but do increase to approximately 50 percent of the total estimated northern bay load. However, the AWT Plant loads must be analyzed in terms of estimated loads into all of Hillsborough Bay, not only the northern portion.

The northern portion of Hillsborough Bay and parts of McKay Bay include the Port of Tampa as well as intensive industrial activity, resulting in a large concentration of point sources in a relatively small area. The point sources contribute 2-4 percent of the total flow (exclusive of power plant thermal discharges) entering the northern bay segment. The pollutant loads associated with the point sources generally vary from 4-11 percent, exception for SS during the dry months and TP throughout the year. The relative load component for SS increases to 24 percent during the dry months due to reduced background SS levels in the Hillsborough River. The TP loads also increase from a wet month relative load of 24 percent to a dry month load of 36 percent due to the reduced TP component in the Hillsborough River.

The impact of non-point pollutant loads is still significant but much less pronounced in Northern Hillsborough Bay. The urban runoff flows constitute only 4-9 percent of the total flow component but the runoff pollutant loads contribute 11-19 percent of the total loads, exclusive of TP which is depressed due to natural background levels in Hillsborough River. The relative load components of BOD and SS increase during the dry months while the relative load component for TN remains constant.

Entire Hillsborough Bay Segment - This last segment of the detailed conceptual model combines the northern Hillsborough Bay segment with the southern portion of the Bay, including additional point sources and the Alafia River. Table 5-5 schematically presents this model and summarizes the individual flow and load components.

TABLE 5-8: TYPICAL WET AND DRY MONTH LOAD VALUES DETAILED CONCEPTUAL MODEL - ENTIRE HILLSBOROUGH BAY


Hillsborough River (INCLUDES: Point, Non-Point and Dam Release contributions from Lower Hillsborough River Segment)
AWT Plant
Alafia River
Discharges directly to Bay:
Point Sources
Non-Point Sources
ENTIRE HILLSBOROUGH BAY

	INDIVIDUAL COMPONENTS					
				Direct Bay Discharge		
Wet Month	AWT Plant	Hillsborough River	Alafia River	Point Sources	Non-Point Sources	Combined
Monthly Volume (acre-feet)	4,170 (6)	37,300 (50)	29,100 (39)	2,320 (3)	1,920 (3)	74,800
Average Flow Rate (MGD)	45 (6)	399 (50)	312 (39)	25 (3)	21 (3)	802
Biochemical Oxygen Demand (lbs)	63,900 (15)	188,000 (45)	118,000 (28)	12,500 (3)	37,100 (9)	420,000
Suspended Solids (lbs)	32,100 (2)	1,054,000 (57)	473,000 (25)	157,000 (8)	145,000 (8)	1,860,000
Total Nitrogen (lbs)	31,000[1] (14)	51,000[2] (23)	120,000[2] (54)	7,200[3] (3)	12,900[4] (6)	222,000
Total Nitrogen (lbs)	31,000[1] (3)	271,000[1] (30)	369,000[1] (64)	7,200[3] (1)	12,600[4] (1)	891,000
Total Phosphorus (lbs)	38,100 (10)	47,500 (12)	264,000 (66)	40,000 (10)	5,820 (1)	398,000
Dry Month						
Monthly Volume (acre-feet)	4,170 (11)	12,900 (35)	15,700 (43)	2,320 (6)	1,730 (5)	36,800
Average Flow Rate (MGD)	45 (11)	138 (35)	169 (43)	25 (6)	19 (5)	396
Biochemical Oxygen Demand (lbs)	63,900 (29)	56,200 (26)	65,600 (29)	12,500 (6)	22,300 (10)	222,000
Suspended Solids (lbs)	32,100 (4)	217,000 (25)	389,000 (44)	157,000 (18)	82,900 (9)	878,000
Total Nitrogen (lbs)	31,000[1] (31)	19,300[2] (19)	35,400[2] (35)	7,200[3] (6)	7,620[4] (8)	101,000
Total Nitrogen (lbs)	31,000[1] (10)	102,000[1] (32)	168,000[1] (53)	7,200[3] (2)	7,620[4] (2)	316,000
Total Phosphorus (lbs)	38,100 (16)	11,400 (5)	143,000 (61)	40,000 (17)	1,870 (1)	234,000

KEY: 906 = Monthly load in units specified
(2) = Relative contribution as a percentage of the combined value

NOTES:
1. Nitrogen Load based on Technicon Auto-Analyzer TKN method
2. Nitrogen Load based on Orion Probe TKN method
3. Nitrogen Load based on NPDES and/or FDER Discharge Permit
4. Nitrogen Load based on USGS multiple regression analysis equation

The inclusion of the Alafia River flows and loads has substantial impact on the relative role of all other components contributing to Hillsborough Bay. In terms of relative volumetric contribution, the Alafia and Hillsborough Rivers differ by only 8-11 percent on mean monthly discharge. However, the pollutant loads are much higher in the Alafia River due to significantly higher pollutant concentrations, excluding wet month BOD and SS loads. The following tabulation presents the ratio of typical monthly loads for the Alafia River vs Hillsborough River for both wet and dry months:

	Load Ratio	
	Wet Month	Dry Month
BOD	0.63	1.13
SS	0.45	1.79
TN	2.35	1.83
TP	5.56	12.54

(Note: Load Ratio = (Alafia Load) ÷ (Hillsborough Load)

The combined loads from the two rivers are by far the dominant factor in the total discharge picture. Combined flows represent 78-85 percent of the total flows and contribute 55-83 percent of the total pollutant loads.

The Tampa AWT Plant, the largest point source in terms of pollutant loads, must be evaluated in the context of the entire Hillsborough Bay system. Certainly, the plant has significant impact on the Northern Bays but the waters of the northern and sourthern protions of the Bay mix with each tidal cycle and the flow and pollutant loads should be viewed from this perspective. Table 5-5 indicates that the relative loads from the AWT Plant are substantially less when compared with all bay system loads versus only the northern bay portion. The following table indicates the differences in these perspectives in terms of ratios of relative impacts.

	Ratio of Relative AWT Plant Loads Wet Month	 Dry Month	 Average
V,Q	0.67	0.52	0.60
BOD	0.71	0.71	0.71
SS	0.72	0.57	0.64
TN	0.45	0.65	0.55
TP	0.31	0.33	0.32

Note: Ratio = (Percent Load with Both Rivers)÷(Percent Load with Hillsborough River)

The effect of the Alafia River on the point source component (excluding the Tampa AWT Plant) is to reduce the relative loads displayed for the Northern Hillsborough Bay Segment. As shown below, the Alafia River substantially alters the relative load contribution of the point sources even though there are additional point sources discharging into the system.

	Ratio of Relative Point Source Loads Wet Month	 Dry Month	 Average
V,Q	1.50	1.33	1.44
BOD	0.75	0.75	0.75
SS	1.00	0.75	0.83
TN	0.43	0.63	0.53
TP	0.42	0.47	0.45

Note: Ratio = (Percent Load with Both Rivers)÷(Percent Load with Hillsborough River)

The impact of the total laod increase due to the inclusion of the Alafia River causes the combined loads for the individual pollutants to reduce the net impact of direct urban runoff on the entire bay. As shown below, the Alafia significantly reduces the relative load contribution of urban runoff for BOD, SS, and TN.

	Ratio of Relative Urban Runoff Loads		
	Wet Months	Dry Months	Average
V,Q	0.75	0.55	0.65
BOD	0.75	0.75	0.73
SS	0.73	0.47	0.60
TN	0.50	0.67	0.59
TP	0.20	0.50	0.35

Note: Ratio = (Percent Load with Both Rivers) ÷ (Percent Load with Hillsborough River)

The exception to this statement is the phosphorus loads which are reduced to 20-50 percent of their former impact due to the high phosphorus load of the Alafia River. Again, the loads associated with urban runoff in this segment represent only the loads generated by the three urban basins which discharge directly to Hillsborough Bay and do not represent all the urban runoff eventually entering the Hillsborough Bay system.

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VI. RECEIVING WATER ASSESSMENT

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INTRODUCTION

This section describes an assessment of recently collected data available in Hillsborough Bay, lower Hillsborough River and Hillsborough Reservoir. The assessment focuses on changes in these water bodies during wet weather conditions. This section also provides separate assessments of the water quality models that have been used in these receiving waters.

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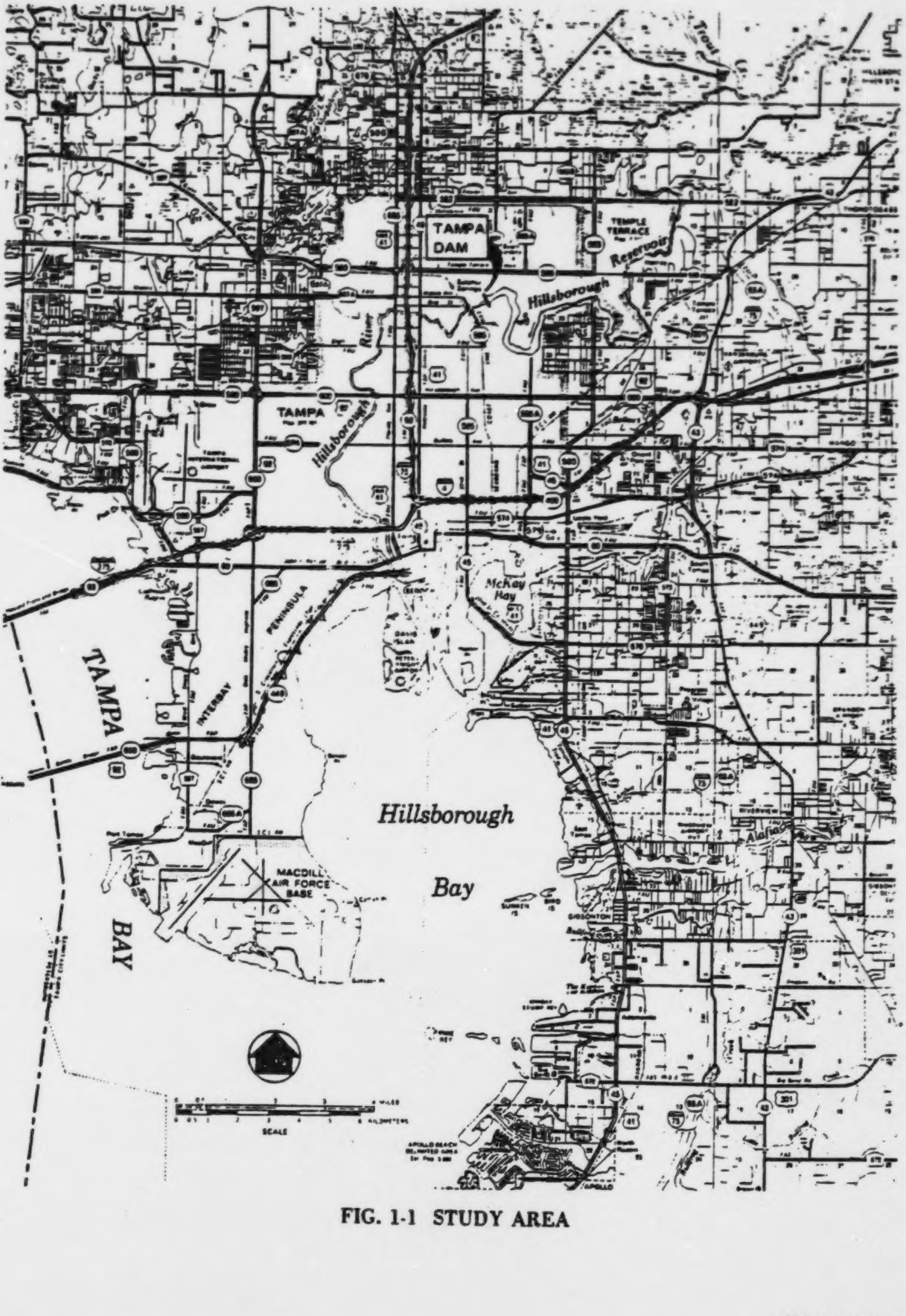
TAMPA DAM
TEMPLE TERRACE
Hillsborough Reservoir
Trout Cr.
Hillsborough River
TAMPA
McKay Bay
TAMPA BAY
INTERBAY
PENINSULA
MACDILL AIR FORCE BASE
Hillsborough Bay
GIBSONTON
RIVERVIEW
Alafia River
SCALE

FIG. 1-1 STUDY AREA

HILLSBOROUGH BAY

General

Hillsborough Bay is located in the northeast section of Tampa Bay. It has a surface area of about 35 square miles, an average depth of about 10 feet at mean low water and a volume of about 9.76 X 10^9 cubic feet(1). A map of Hillsborough Bay is presented in Figure 1-1. Several major navigation channels are maintained in the Bay. Dredging of the channels and creation of spoil islands and circulation cuts is an on-going function of the Corps of Engineers.

Data Base Summary

Data collected in Hillsborough Bay have been reviewed for the purpose of analyzing the impacts of wet weather on that water body. The following paragraphs summarize the data base used for this purpose.

Bathymetric information is available from NOAA through nautical charts published annually. Two charts are available which, together, cover the whole of Tampa Bay. The bathymetry of Hillsborough Bay is continually changing due to widening and maintenance dredging of shipping channels by the Corps of Engineers.

A "circulatory survey" of tidal currents in Tampa Bay was performed in 1963 by the U.S. Coast & Geqdetic Survey(2). One station in Egmont Channel was occupied for about one month, and forty other locations in Tampa Bay were occupied for about four days. The sampling interval was one-half hour. These data are used for the daily predictions of tidal current at Egmont Channel. Correction factors to the other stations are also presented. The publication presents maximum ebb and flood velocities only. Predictions of Tampa Bay tides are also published annually by NOAA, with the major prediction station in St. Petersburg, and corrections to about fourteen other stations.

Tides and currents were also measured by the USGS in Tampa Bay and used to calibrate a mathematical model. Fourteen tide gages were in place from about 1971 to 1976, and eleven current meters were in place for two weeks in 1972. This information is the most up-to-date and comprehensive information available on simultaneous measurement of tides and currents.

Numerous water quality sampling programs have been conducted in the Tampa Bay region. These programs have consisted of collection of data to show long-term trends (seasonal and annual), rather than data collected to show the conditions before, during, and after a storm. However, certain sampling periods during these programs were conducted during the wet season, and others were conducted after rainstorms. These data may be interpreted in light of these wet and dry periods. Data is available for the most recent and comprehensive programs including:

1. Hillsborough County Environmental Protection Commission (HCEPC) data.

2. City of Tampa data.

The HCEPC sampling program has been conducted about once per month in Tampa Bay since 1972. A summary of the data is presented in annual reports. The location of the sampling stations are presented in Figure 2-1. There are about 15 stations in Hillsborough Bay and 39 stations in the rest of Tampa Bay.

The sampling dates for the HCEPC program conducted during 1979 are shown in Figure 2-2 along with rainfall at the Tampa International Airport. The year 1979 was chosen for detailed analysis. The August 22 and September 19 samples fall within the wet season. The March 7 sample is one day after about 1.7 inches of rain and the May 30 sample occurs after two large storms in May, including the rainstorm of about twelve inches on May 8.

The City of Tampa sampling program began in 1976 and is on-going. The program is conducted about once every two weeks, and the location of the stations are also presented in Figure 2-1. Since its inception, the program has undergone several changes. Originally, measurements were made primarily of chemical parameters. More recently measurements have been shifted toward biological parameters such as productivity.

The City of Tampa sampling dates during 1979 are shown in Figure 2-2. In June all stations were eliminated but 4 and 1112, and station number 13 (in Tampa Bay one mile from the entrance to Hillsborough Bay) was added in August. At present, the emphasis in the program is on measurements of biological related parameters.

Data Analysis

The purpose of this section is to present and analyze receiving water data from the key sampling programs in Hillsborough and in Tampa Bay. Spatial and temporal trends are discussed, and the effect of wet weather on the parameters is considered. Parameters discussed include salinity, flushing, circulation, oxygen resources, solids and turbidity, coliform

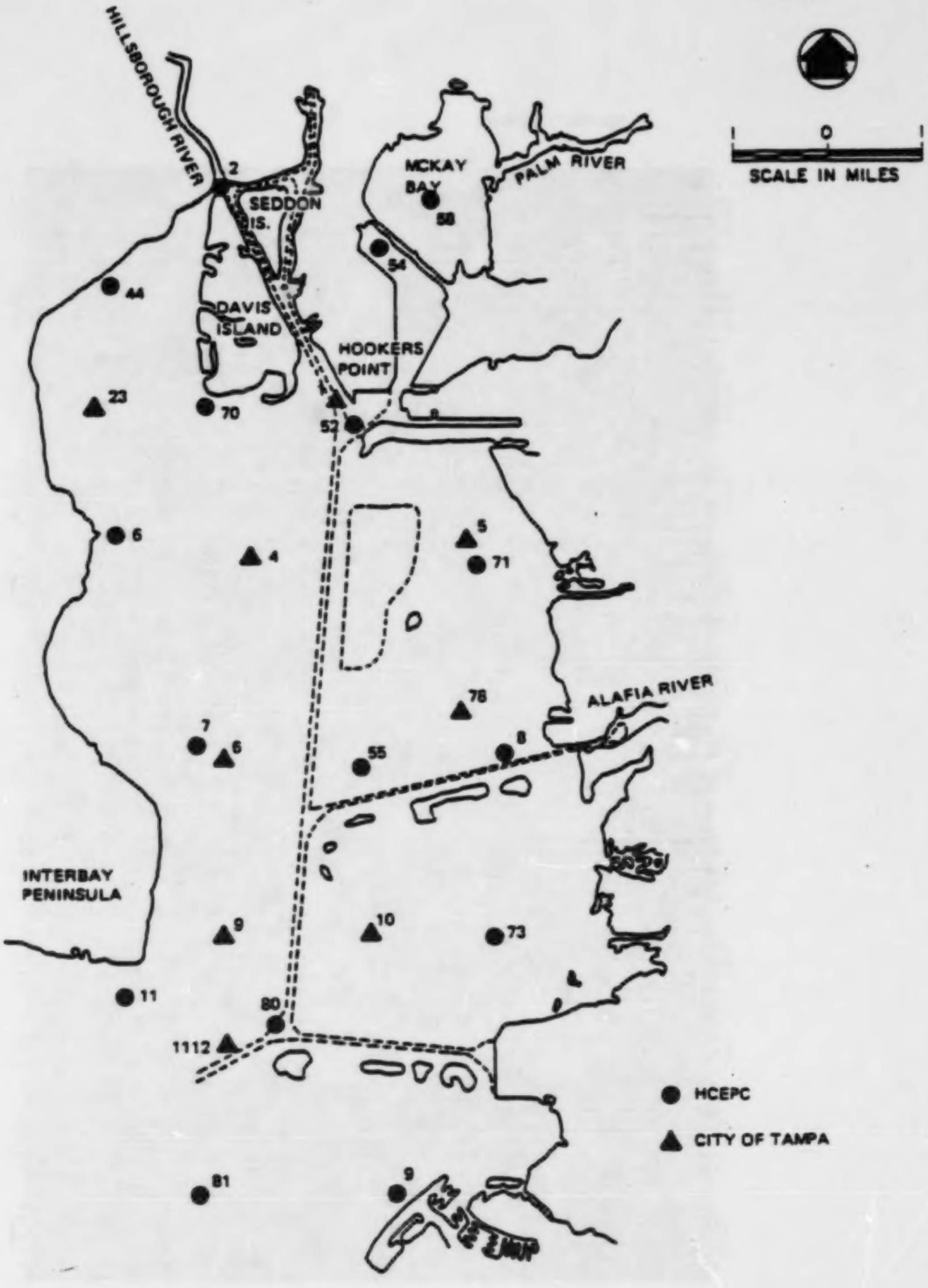
HILLSBOROUGH RIVER
2
SEDDON IS.
DAVIS ISLAND
HOOKERS POINT
MCKAY BAY
58
PALM RIVER
54
44
23
70
52
6
4
5
71
76
ALAFIA RIVER
7
6
55
8
INTERBAY PENINSULA
9
10
73
11
80
1112
81
9
● HCEPC
▲ CITY OF TAMPA
0
SCALE IN MILES

FIG. 2-1 WATER QUALITY SAMPLING STATIONS – HILLSBOROUGH BAY, 1979

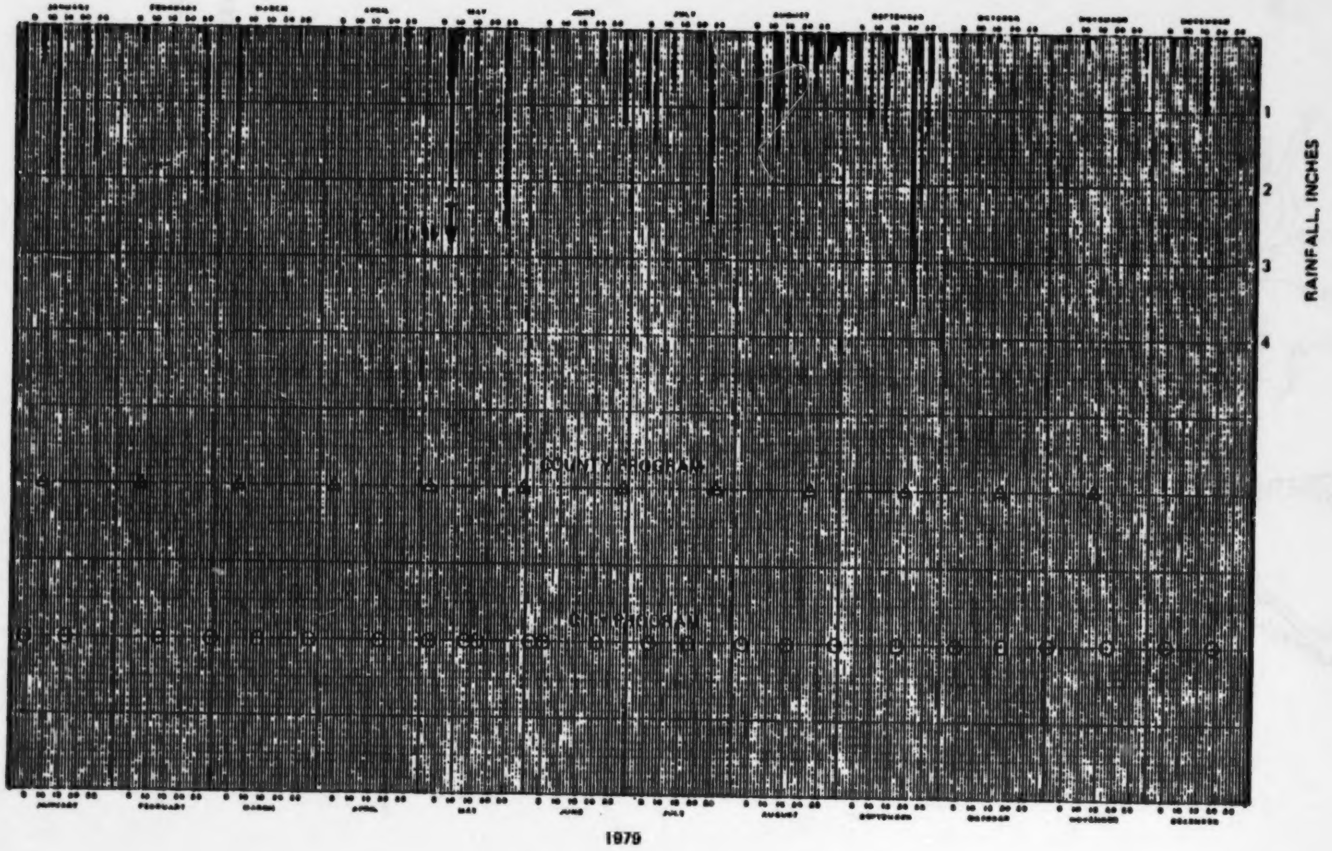

FIG. 2-2 WATER QUALITY SAMPLING DATES – HILLSBOROUGH BAY, 1979

bacteria, and nutrients. The discussion of water quality parameters will center on the year 1979, since it is the most recent year in which a full year of data is available, and since data during this time period are also available for the lower Hillsborough River and the Hillsborough Reservoir. Also, due to the recent improvements at the Hookers Point Wastewater Treatment Plant, water quality in 1979 is least affected by the plant discharge. More rainfall occurred during 1979 than during the three previous years, increasing the opportunity to study the impact of urban stormwater runoff. Sanitary sewer overflows were reported in the lower Hillsborough River during 1979 and thus increase the difficulty in distinguishing the impact of stormwater runoff. This situation is recognized and where appropriate conditions are assessed in McKay Bay where sanitary sewer overflows have not been reported, or are compared to data from other years.

In the following analysis yearly trends are presented by plotting the average of all data taken in Hillsborough Bay on a given day. In cases where concentrations at one station or location are markedly different than others, it is presented and discussed separately. In addition, concentrations throughout the Bay are presented for some parameters to demonstrate spatial variations at critical time periods, normally during wet weather. In each figure where average concentrations are presented, one standard deviation from these concentrations are given in Appendix A.

Salinity. Since salinity is a conservative parameter and is a function of freshwater flow, the concentration variations indicate the direct impact of freshwater flow on the Bay. Freshwater flow contributes to flushing of the Bay. The density of ocean water is a function of salinity, and density variations affect the mixing properties of the Bay,.

A plot of salinity during 1979 at the upper end of Hillsborough Bay, the mouth of Hillsborough Bay, and the mouth of Tampa Bay, is shown in Figure 2-3. The typical salinity concentrations in Hillsborough Bay range from about 15 to 25 parts per thousand (ppt). Hillsborough Bay receives a large portion of the freshwater inflow that ultimately discharges into Tampa Bay, thus the salinity increases considerably going from the upper end of Hillsborough Bay to the mouth of Tampa Bay. The variation from the upper end to the mouth of Hillsborough Bay increases during the wet season resulting from the increased freshwater input. Also during the wet season (August and September), the salinity of all stations drops in response to the high flows. The spatial variation of salinity concentrations in Hillsborough Bay is shown for a day in September during the wet season in Figure 2-4. A difference of approximately 10 ppt from the mouth of the Hillsborough River to the southerly portion of Hillsborough Bay is evident. The flows measured on this day by the USGS were 1,690 cfs at the Tampa Dam on the Hillsborough River and 1,220 cfs at

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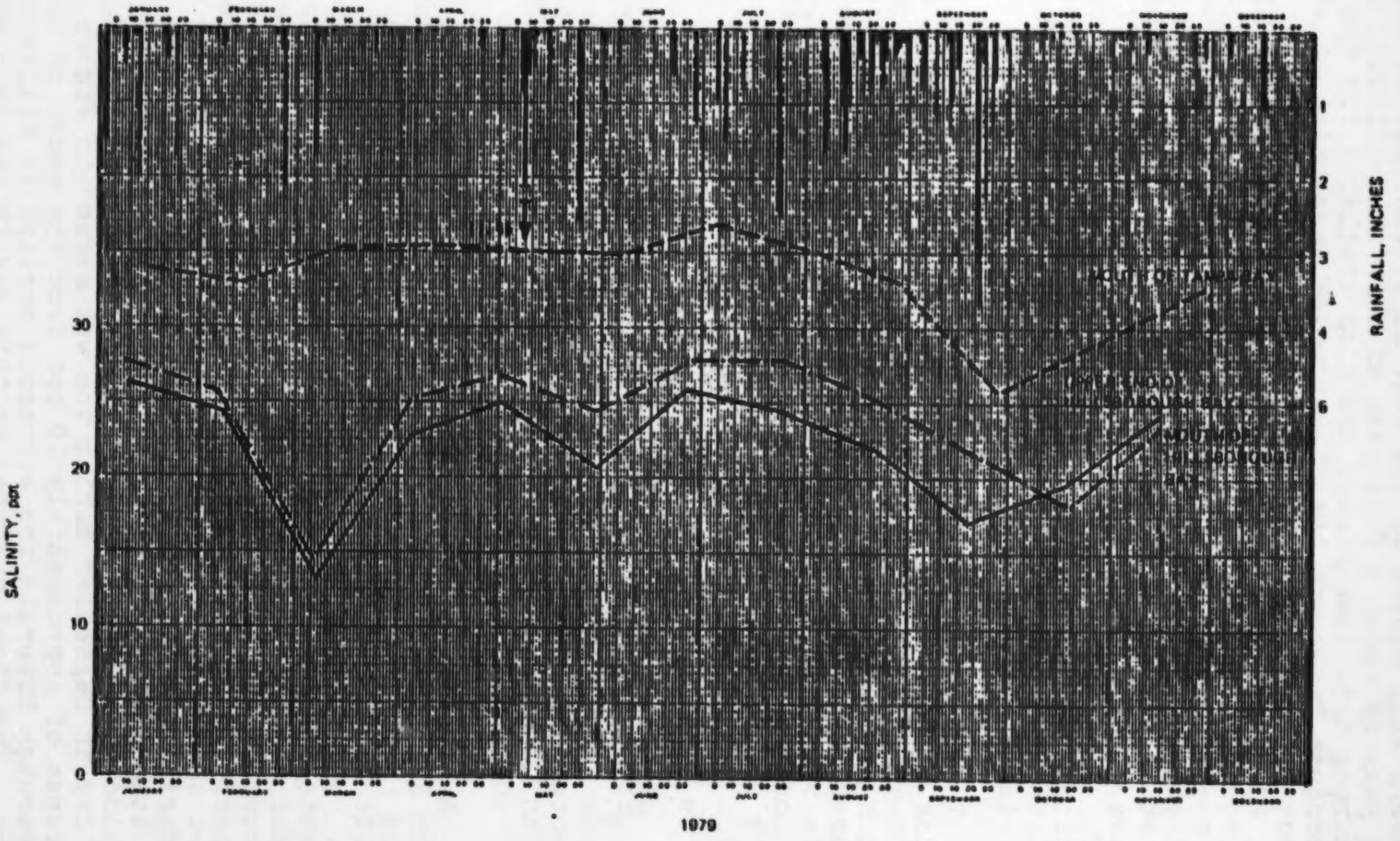

FIG. 2-3 SALINITY CONCENTRATIONS IN HILLSBOROUGH AND TAMPA BAY, 1979

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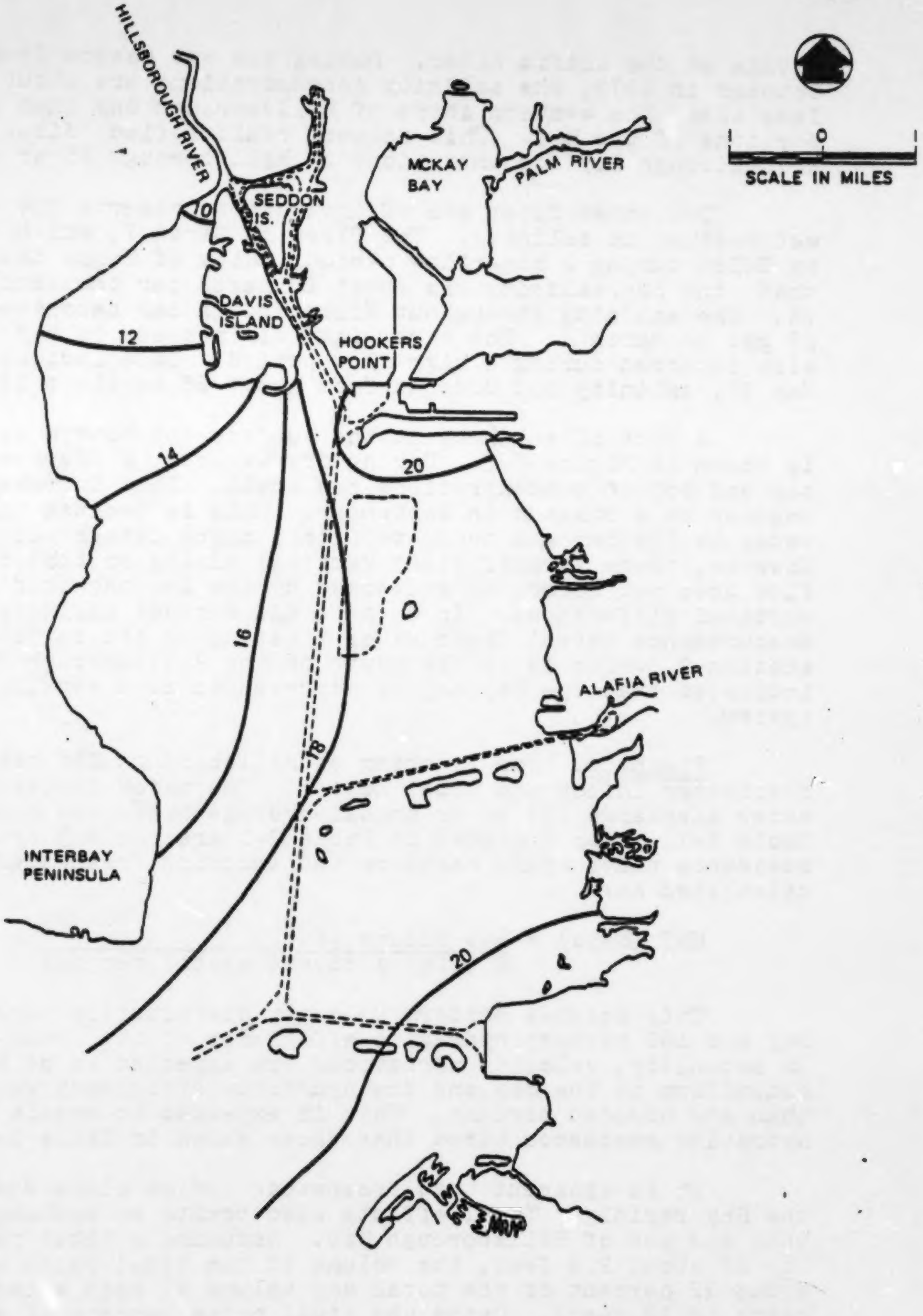
HILLSBOROUGH RIVER
SEDDON IS.
MCKAY BAY
PALM RIVER
0
1
SCALE IN MILES
10
DAVIS ISLAND
12
HOOKERS POINT
14
20
16
ALAFIA RIVER
18
INTERBAY PENINSULA
20

FIG. 2-4 SALINITY CONCENTRATIONS HILLSBOROUGH BAY – SEPTEMBER 19, 1979

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Lithia on the Alafia River. During the wet season from July to October in 1979, the salinity concentrations are about 5 to 10 ppt less along the western shore of Hillsborough Bay than in other portions of the Bay. This pattern could reflect dilution of Hillsborough Bay concentrations by Hillsborough River water.

Two other dates are of interest to observe the effect of wet weather on salinity. The first is March 7, which was sampled by HCEPC during a high flow period. City of Tampa data indicate that the Bay salinity was about 20 parts per thousand on February 28. The salinity throughout Hillsborough Bay decreased to about 15 ppt on March 7. The other date of interest is May 30, which also occurred during a high flow period. Data indicate that on May 30, salinity had dropped from about 25 to about 22 ppt.

A plot of salinity at the surface and bottom at station 52 is shown in Figure 2-5. During dry weather, differences between top and bottom concentrations are small. They increase during wet weather to a maximum in September. This is because the fresh water is lighter and tends to float on the denser saline water. However, there is sufficient vertical mixing so that two layer flow does not occur, as evidenced by the low magnitudes of the vertical differences. In no case did surface salinity measurements reveal fresh water floating on the surface, except at station 2, which is at the mouth of the Hillsborough River. This indicates that the Bay may be represented as a vertically mixed system.

Flushing. The flushing of Hillsborough Bay results from freshwater inflow and tidal motion. The major inputs of freshwater discharge (Q) on an annual average basis are summarized in Table 2-1. Also included in Table 2-1 are the Bay hydraulic residence times (HRT) based on the incoming freshwater flow and calculated as:

$$\text{HRT (days)} = \frac{\text{Bay Volume (ft}^3\text{)}}{\text{Q (cfs)} \times 86{,}400 \text{ second per day}}$$

This assumes uniform velocity distribution throughout the Bay and 100 percent hydraulic efficiency of the cross-sections. In actuality, velocity variations are expected to be somewhat nonuniform in the Bay and the hydraulic efficiency would be less than one hundred percent. This is expected to result in smaller hydraulic residence times than those shown in Table 2-1.

It is apparent that freshwater inflow alone does not flush the Bay rapidly. Tidal effects also create an exchange of water into and out of Hillsborough Bay. Assuming a tidal range in the Bay of about 2.8 feet, the volume of the tidal prism would be about 22 percent of the total Bay volume at high water (average depth of 10 feet). Using the tidal prism concept of estuary mixing, this would indicate that 22 percent of the water is exchanged during each tidal cycle, or about 42 percent per day.

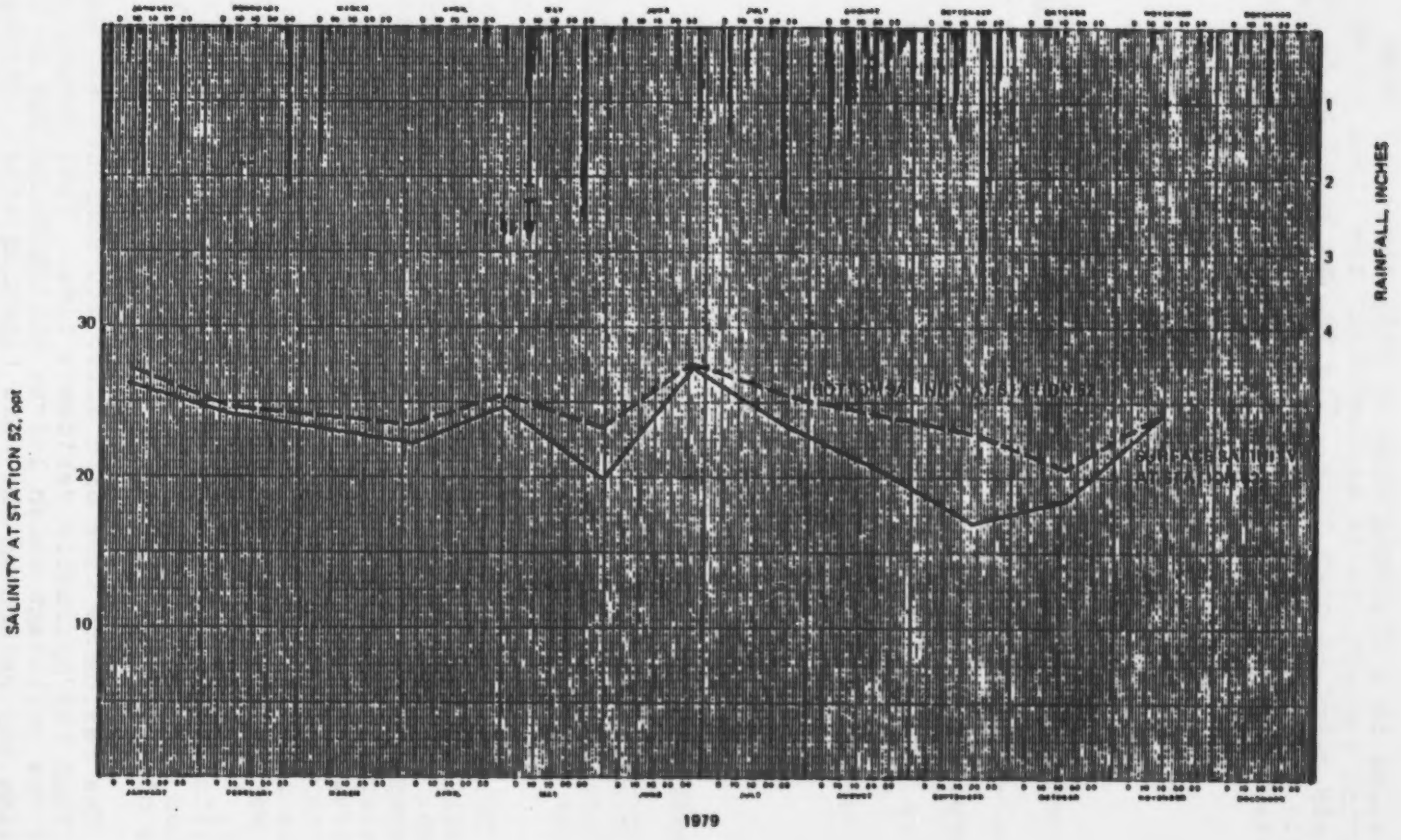

FIG. 2-5 SURFACE AND BOTTOM SALINITY CONCENTRATIONS, HILLSBOROUGH BAY, 1979

This results in a flushing time of only about 2.4 days. Using the tidal prism concept, it is assumed that the tidal prism volume is completely mixed at high tide. The volume which is actually available for dilution of a dissolved substance is limited by the tidal excursion or the distance a particle would travel on a flood tide.

TABLE 2-1. FRESHWATER DISCHARGE AND HYDRAULIC RESIDENCE TIMES OF HILLSBOROUGH BAY

	Freshwater Discharge(1) (cfs)		
	Average flow	Low flow	High flow
Hillsborough River	620	200	2,000
Alafia River	380	120	1,200
Palm River	60	20	200
Other(2)	110	30	340
Total	1,170	370	3,740
HRT (days)	97	300	39

1. Source - USGS Surface Water Records.
2. Estimated as an addition 10 percent contribution from drainage areas not included in other sources.

To account for incomplete mixing limited to a distance of the tidal excursion, Ketchum (3) developed a modified tidal prism approach. In this approach, the Bay is divided into segments in which complete mixing occurs. The segment lengths approximate the tidal excursion distances. Such a calculation was carried out for Hillsborough Bay for the high flow condition assuming that the Bay was rectangular (about 25,000 feet wide and 39,000 feet long) and that the inflows enter at the upstream end. The Alafia River volume was not included for dilution since it enters further down the Bay, to ensure conservative results. The modified tidal prism calculation results in a residence time of about 21 days. This is less than the value of 39 days obtained by using the Bay volume and the high freshwater flow.

The residence time of a dissolved constitutent may be longer than the hydraulic residence time. This occurs because some of the pollutant which leaves Hillsborough Bay on the outgoing tide may return on the next flooding tide. Mixing of the Hillsborough Bay waters with the Tampa Bay waters may be limited such that some of the Hillsborough Bay water that leaves the Bay on ebb tide returns on flood tide. This "old" water is therefore not available for dilution, and as a result the pollutant residence times would be increased. To determine the pollutant residence time more accurately, either a model study would be needed or detailed field measurements would be required including measurements at the Hillsborough Bay-Tampa Bay boundary.

Circulation. Three modeling studies of hydrodynamic circulation in Tampa Bay have been performed by the University of South Florida(4), the USGS(1), and the Tampa Electric Company(5). Controversy exists as to the exact circulation pattern in Hillsborough Bay. The USGS model predicts a counter-clockwise circulation in Hillsborough Bay. The USF model predicts the existence of several gyres or rotary currents, three of which are located in Hillsborough Bay and one just south of the Interbay Peninsula. These circulations are based on net velocities computed over a tidal cycle. Also using this method to calculate net circulation, the model CAFE (as used by TECO) predicts a predominantly counter-clockwise circulation pattern in Tampa Bay. This is attributed to the angle between Tampa Bay and the Gulf of Mexico, which is said to direct flood tide flows along the deeper eastern shore(5). In addition, the gyre south of Interbay Peninsula is predicted as in the USF model results. The grid size in the CAFE model in Hillsborough Bay is large, as compared to the USF model, and therefore could not be used to check the smaller gyres predicted by the USF model.

Salinity data in 1979 show that the concentrations along the western shore are generally lower than those along the eastern shore during wet weather (see Figure 2-4). Presumably, the freshwater flow from the Hillsborough River would dilute the western shore concentrations. This effect appears to cause a larger net outflow along the western shore, and may contribute to a counter-clockwise circulation.

Since current data used for model calibration has not been taken since 1972, and because of alterations in the Bay caused by the on-going dredging program, new oceanographic data may be necessary to verify the existing circulation pattern in the Bay.

Dissolved Oxygen Resources. Figure 2-6 is a plot of near surface and near bottom average dissolved oxygen (DO) in Hillsborough Bay during 1979. Figure 2-6 represents average values of all top and bottom samples taken on a given day approximately once per month. Also shown are the estimated saturation levels of DO, calculated from temperature and salinity values in the Bay. The surface DO was near saturation or super-saturated during most of the year. Through the high flow period and into October, the surface DO drops and the deficit increases. The bottom DO drops below saturation in March and is about 2 mg/l below saturation by July. During the wet season, the largest increase in the bottom DO deficit occurs. The seasonal trend of larger deficit during wet weather was true for all stations in Hillsborough Bay, as shown by averaging the Bay stations.

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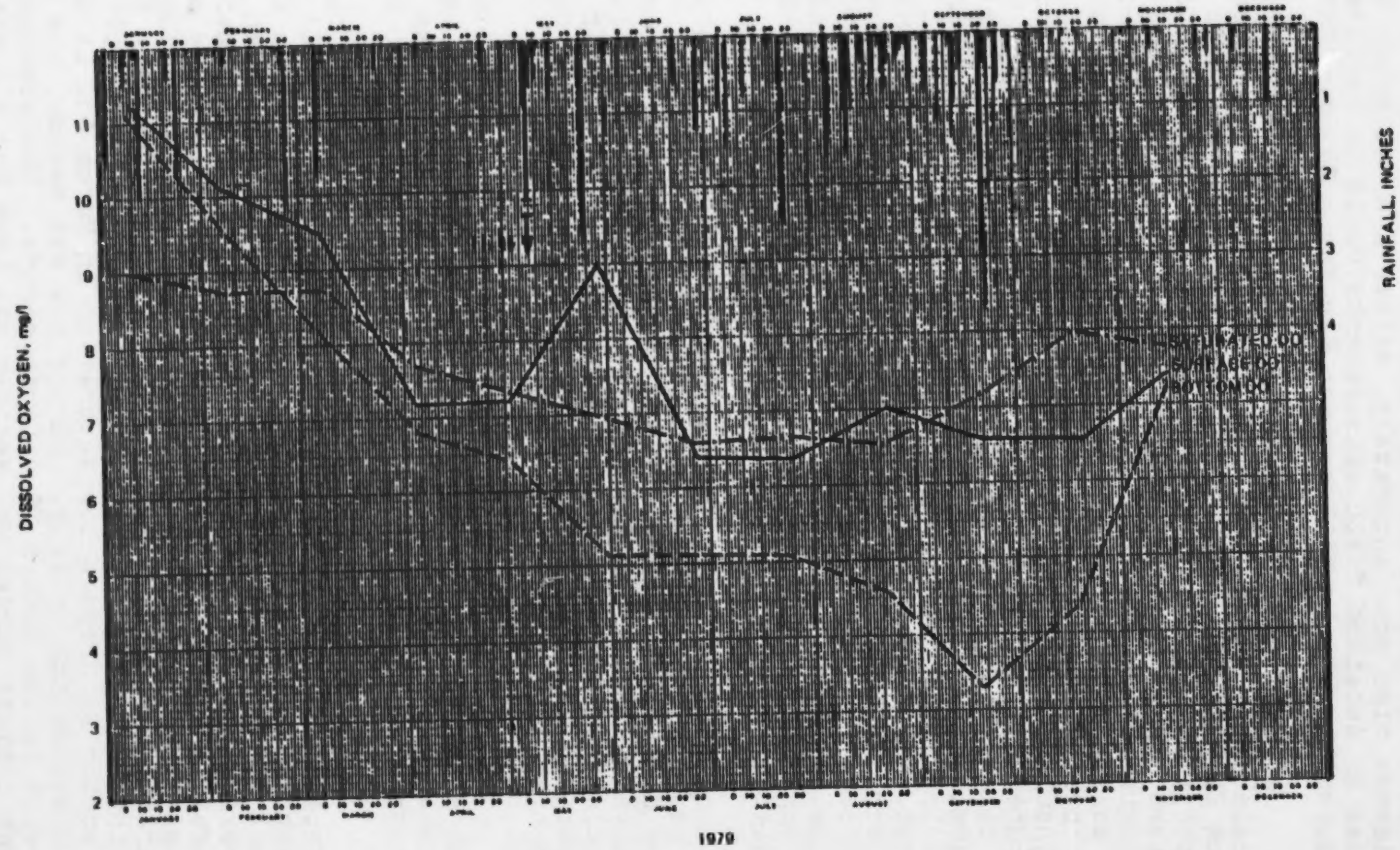

FIG. 2-6 SURFACE, BOTTOM, AND SATURATED DISSOLVED OXYGEN CONCENTRATION – HILLSBOROUGH BAY, 1979

Variations do however exist within the Bay. These variations are shown in Figure 2-7 which is a plot of the bottom DO in September. This is the worst DO condition during the year, and the middle and upper portions of the Bay are below the State standards of 4.0 mg/l. The worst bottom DO concentrations are along the western shore, possibly due to the Hillsborough River source. Conditions are equally poor in McKay Bay, which receives urban runoff largely from the 29th Street drainage basin and the Palm River. The DO trend shown in Figure 2-6 is confirmed in other data sets. The University of South Florida Sea Grant data of 1975(18) clearly show the drop in bottom DO during the wet season with the low point in September. HCEPC plots of bottom dissolved oxygen second minimums in the 1976, 1977, and 1978 annual reports also indicate standards violations. Spatial variations as shown in Figure 2-7 also are generally confirmed by the HCEPC data with the central and western portions of Hillsborough Bay experiencing the lowest DO concentrations during 1976 and 1977.

During the high flow period of March 7, the bottom DO concentrations drop below saturation. During the high flow period in May, a drop in bottom DO and an increase to super-saturation of surface DO occurred. The lower dissolved oxygen concentrations and larger DO deficits, particularly at the bottom, occur during wet weather. A possible explanation for this occurrence is that the reduction in salinity due to increased freshwater flow causes the death of freshwater intolerant algae. The die-off, settling, and decay of these algae would then result in an oxygen demand near the bottom of the water column. Verification of this possibility could be done with field measurements. An additional explanation could be the increased BOD loading to the Bay input by higher flows, or increased sediment oxygen demand during higher temperatures.

Average BOD_5 values in Hillsborough Bay are presented in Figure 2-8. Values are high during January and February, and then drop down to about the 2 to 4 mg/l range. The reduction in BOD_5 parallels improved treatment at the Hookers Point treatment plant. During January and February the operating records show that the plant discharged an average of 14 and 28 mg/l of BOD_5. In addition, there was very little freshwater flow entering the Bay in January and February. During the remainder of the year, the plant discharged from 2 to 9 mg/l of BOD_5.

BOD_5 concentrations measured by HCEPC indicate that during 1976, 1977, and 1978 average concentrations in Hillsborough Bay were greater than 4 mg/l. Concentrations presented in Figure 2-8 average slightly less than 4.0 mg/l. There appears to be a slight decrease in average BOD_5 concentrations in 1979, despite larger overflows.

BOD values do not increase in the wet season during August and September. After the heavy rains of May, however, there is a significant increase of BOD_5. This is illustrated in May 30, 1979

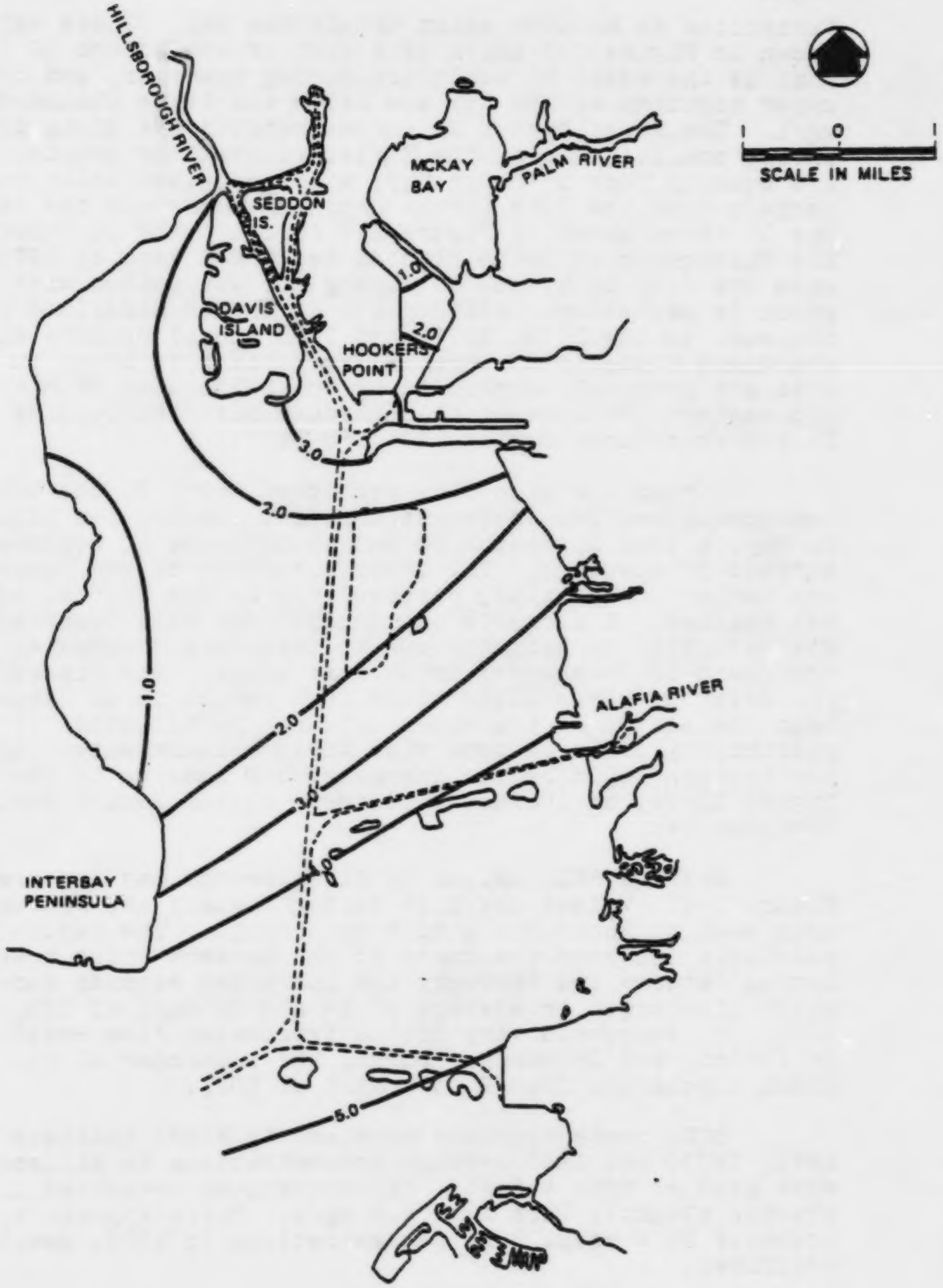
HILLSBOROUGH RIVER
SEDDON IS.
MCKAY BAY
PALM RIVER
DAVIS ISLAND
HOOKERS POINT
1.0
2.0
3.0
2.0
1.0
2.0
3.0
4.0
ALAFIA RIVER
INTERBAY PENINSULA
5.0
1
0
1
SCALE IN MILES

FIG. 2-7 BOTTOM DISSOLVED OXYGEN CONCENTRATIONS
– HILLSBOROUGH BAY, SEPTEMBER 19, 1979

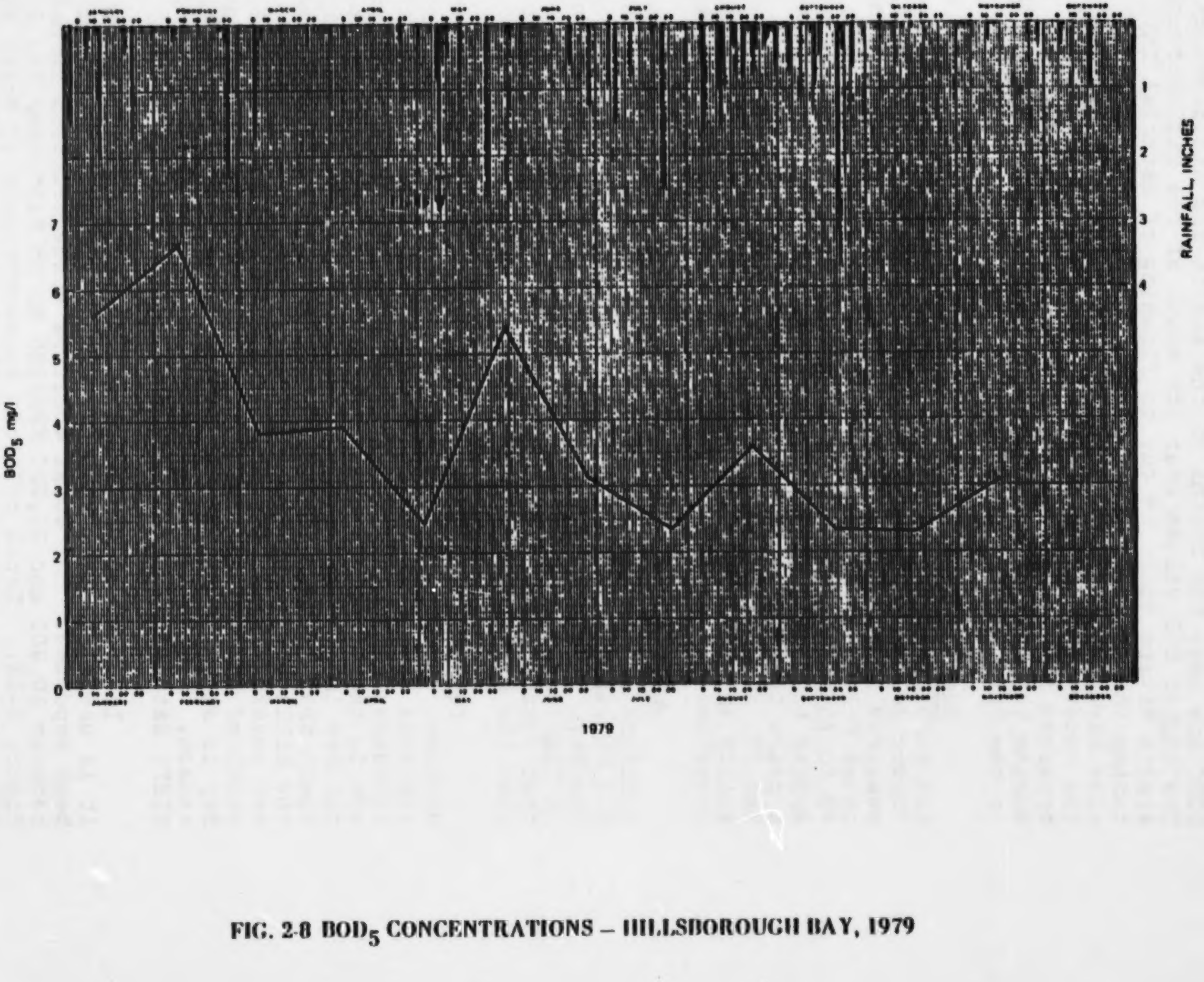

FIG. 2-8 BOD$_5$ CONCENTRATIONS – HILLSBOROUGH BAY, 1979

BOD_5 values plotted in Figure 2-9, and show that areas of high BOD_5 are near the mouths of the Alafia and Hillsborough Rivers. The higher BOD values near the mouth of the Hillsborough and Alafia Rivers could be due to flushing of material into the Bay during the high flow period preceding May 30. The high flows may also have resuspended bottom material increasing organic matter in the water column. The City of Tampa has indicated that raw sewage bypassed into Hillsborough River and subsequently into the Bay during this high flow condition, thus contributing to the BOD load to the Bay.

Suspended Solids and Turbidity. Average values of solids and turbidity during 1979 in Hillsborough Bay are presented in Figure 2-10. These data represent average values for all stations measured in the Bay on a given day. Standard deviations from these values are given in Appendix A. Solids typically range from 45 to 75 mg/l, and turbidity from 5 to 20 NTU's. The trends appear to be the same for these two parameters. Wet weather appears to reduce the solids concentrations such as on March 7, May 30, and during August and September. The large increase in solids in July accompanies a large increase in chlorophyll and therefore may result from an algal bloom during this period.

Total and Fecal Coliform. HCEPC data indicate that total coliform concentrations for stations 44 and 70, near the mouth of the Hillsborough River, are consistently higher than the rest of the Bay. Therefore, these two stations are averaged and plotted in Figure 2-11, as are the other ten stations. It can be seen that concentrations are typically an order of magnitude higher near the Hillsborough River.

Total coliform counts increase substantially during wet weather. During the wet season, coliform concentrations at stations 44 and 70 increase rapidly while the rest of the Bay increases more slowly. Wet weather coliforms at station 44 and 70 are in the 10,000 to 100,000 MPN/100 ml range, while the rest of the Bay is an order of magnitude lower. It is important to note again that during 1979 the City reported raw sewage overflows into the Hillsborough River. This is a contributing factor, along with wet weather flows, to the high coliform counts in the Bay at the mouth of the Hillsborough River. The coliform distribution in the Bay is shown in Figure 2-12 on September 19, 1979, during the wet season. The influence of the Hillsborough River is evident. HCEPC data from previous years confirm this trend.

In order to investigate the impact of raw sewage overflows it is useful to look at McKay Bay, where such overflows have not been reported. The total coliform concentrations in McKay Bay are between 10,000 and 20,000 MPN/100 ml on September 19, 1979 (see Figure 2-12). Total coliform concentrations in McKay Bay during dry weather in 1979 are typically less than 1,700 MPN/100 ml. The increase during wet weather reflects the impact from the Palm River and urban runoff largely from the 29th Street drainage

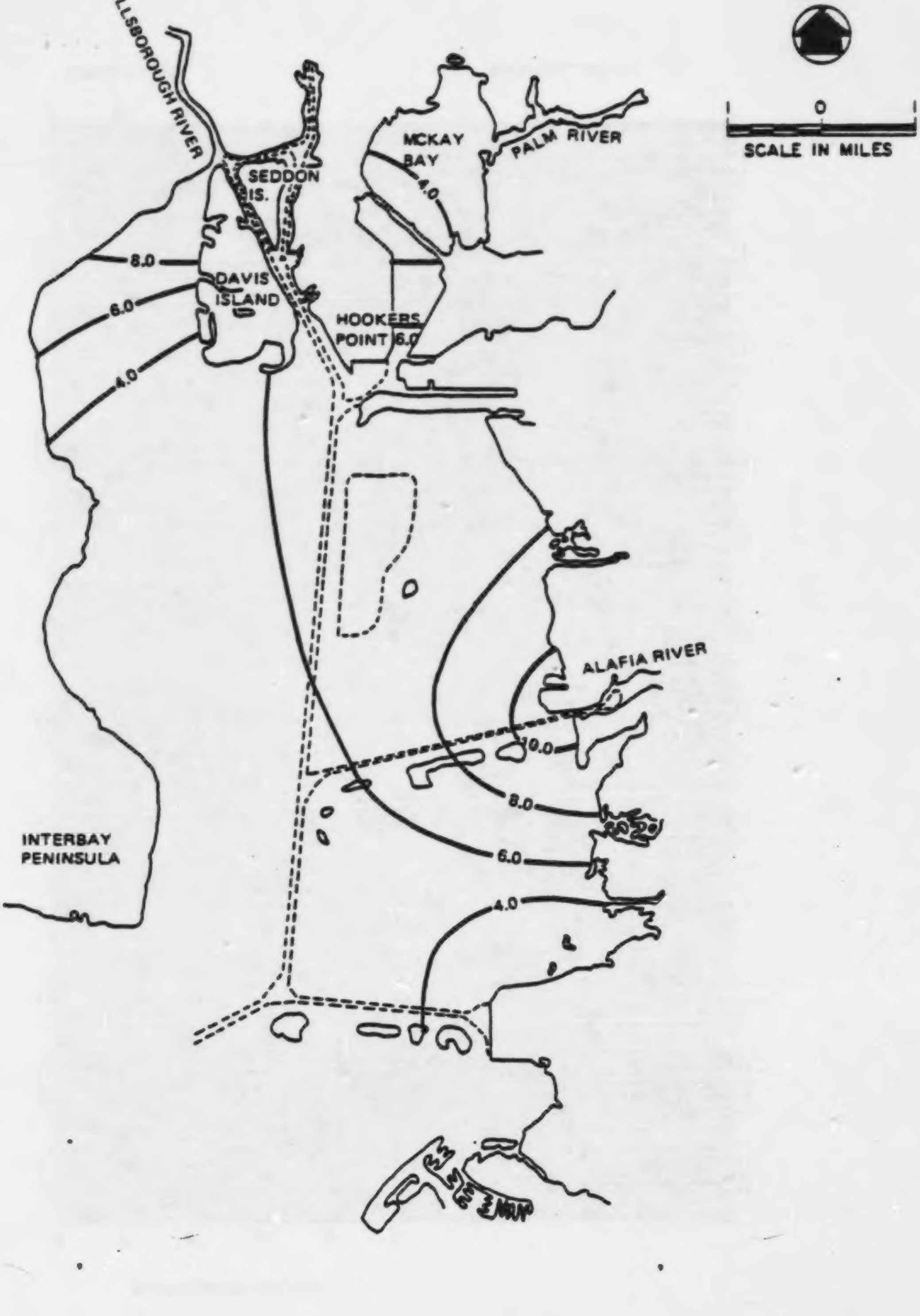
HILLSBOROUGH RIVER
SEDDON IS.
MCKAY BAY
PALM RIVER
0
SCALE IN MILES
4.0
8.0
6.0
4.0
DAVIS ISLAND
HOOKERS POINT
6.0
ALAFIA RIVER
10.0
8.0
6.0
4.0
INTERBAY PENINSULA

FIG. 2-9 BOD$_5$ CONCENTRATIONS – HILLSBOROUGH BAY, MAY 30, 1979

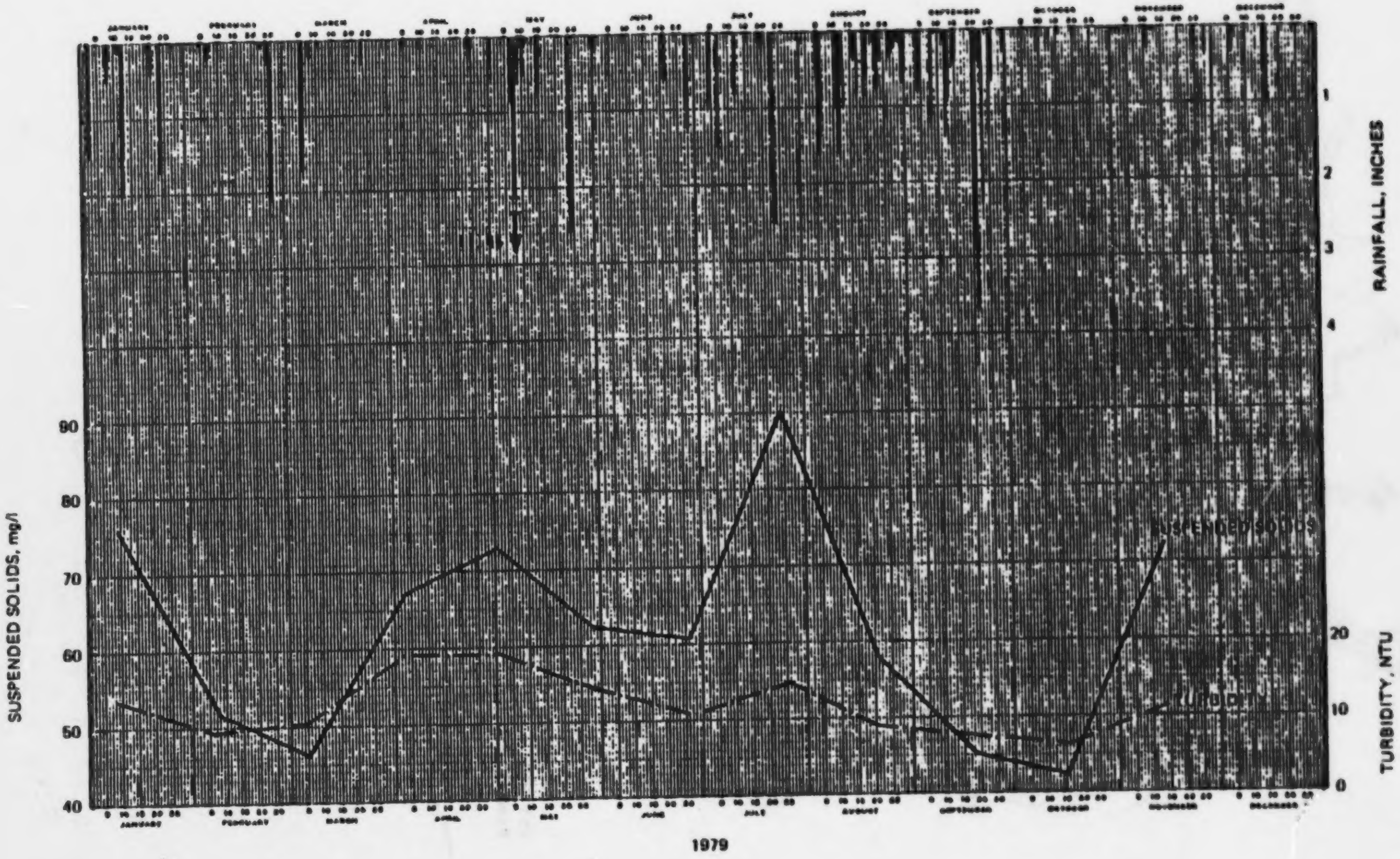

FIG. 2-10 SUSPENDED SOLIDS AND TURBIDITY CONCENTRATIONS – HILLSBOROUGH BAY, 1979

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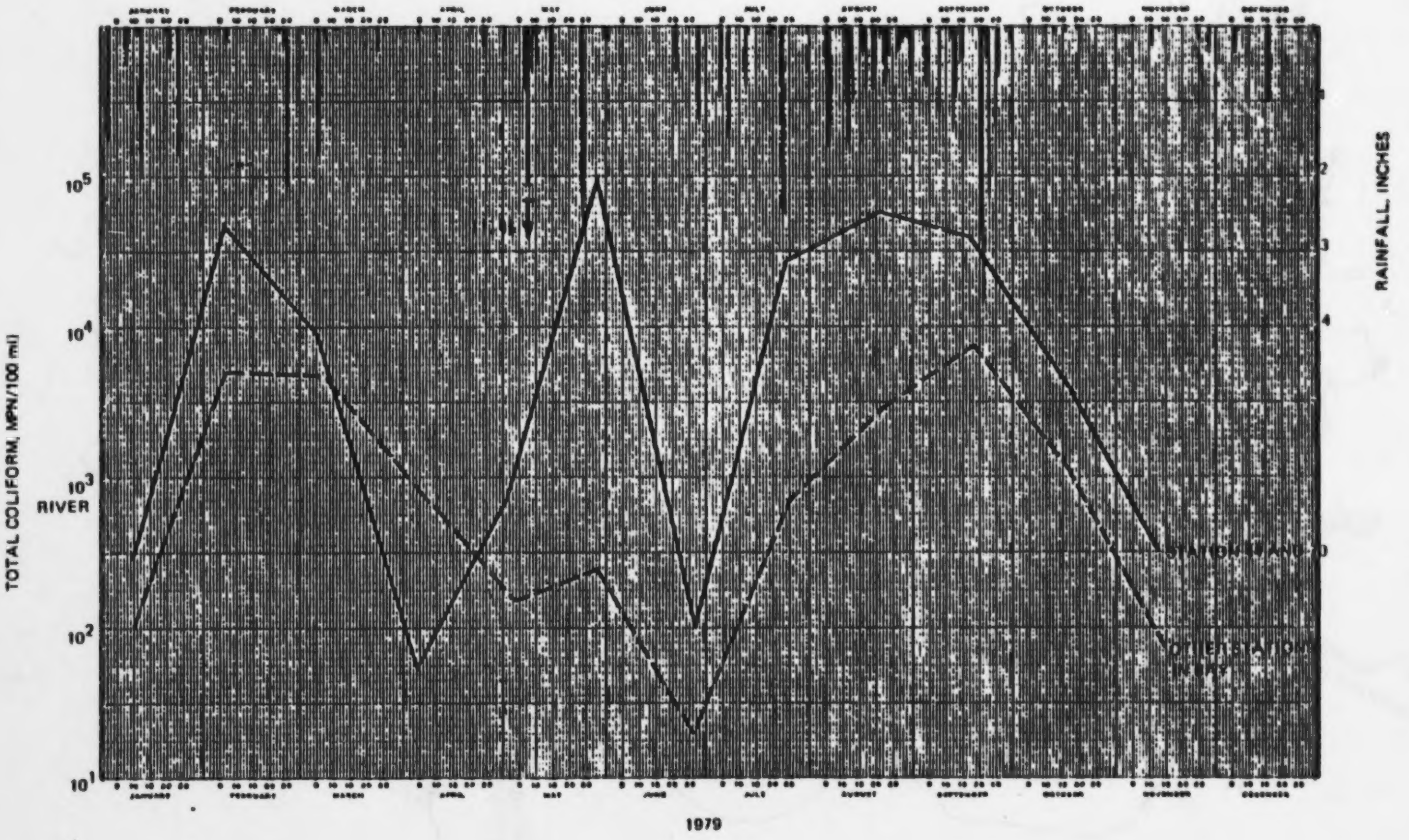

FIG. 2-11 TOTAL COLIFORM CONCENTRATIONS – HILLSBOROUGH BAY, 1979

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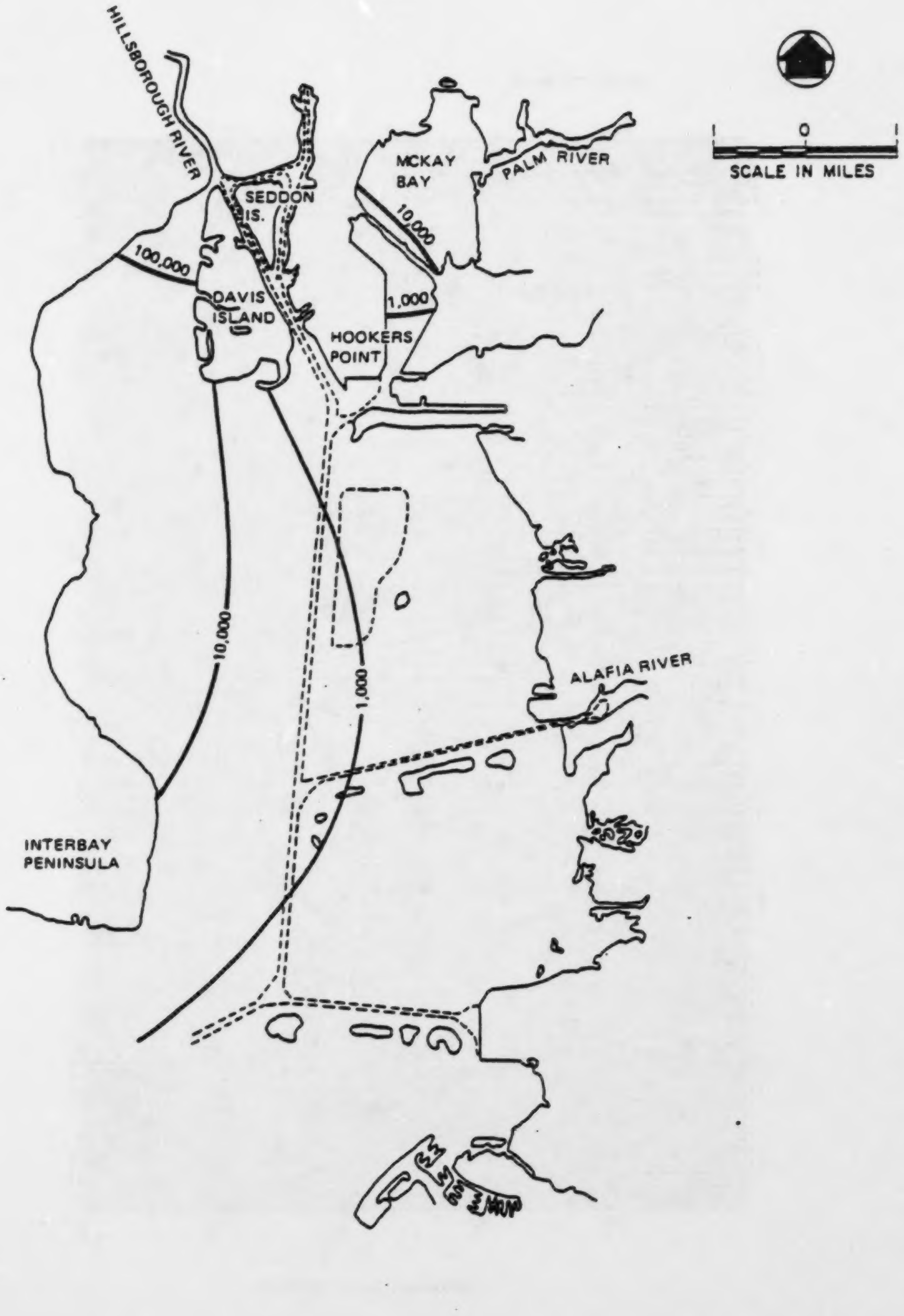
HILLSBOROUGH RIVER
SEDDON IS.
MCKAY BAY
PALM RIVER
SCALE IN MILES
1
0
1
100,000
10,000
1,000
DAVIS ISLAND
HOOKERS POINT
10,000
1,000
ALAFIA RIVER
INTERBAY PENINSULA

FIG. 2-12 TOTAL COLIFORM CONCENTRATIONS – HILLSBOROUGH BAY, SEPTEMBER 19, 1979

basin. The total coliform concentration in the Palm River was measured once during September 1979 (on September 5) by the HCEPC at State Highway 41. The concentration measured was 4,600 MPN/100 ml. The 29th Street drainage outfall was measured nine times by the City during September 1979 and total coliform counts ranged from 520,000 to 2,600,000 MPN/100 ml. Although the data are not conclusive, they suggest that the increase in coliform concentrations in McKay Bay during wet weather may be a function of urban runoff, a large portion of which comes from the 29th Street drainage basin.

For fecal coliform the same pattern is observed as that for total coliform.

Nutrients. Figure 2-13 is a plot of the average total phosphorus concentration in Hillsborough Bay, and near the mouth of the Alafia River. In the first three months of the year, the concentration near the Alafia River is very high. The Alafia River drains a basin rich in natural phosphorus deposits, and with several phosphorus processing plants. It appears as though limitation of this source may have occurred after March. The concentrations of total P in the Bay drop from about 1.5 mg/l to about 0.8 mg/l during 1979. HCEPC phosphorus data collected during 1977 and 1978 range between 1 and 2 mg/l.

Bay phosphorus concentrations do not appear to respond to rainfall. There is an increase in May, after a high flow period, but the concentrations drop during the wet season.

A plot of average nitrate, ammonia, and organic nitrogen in Hillsborough Bay is presented in Figure 2-14. Nitrate concentrations are highly variable in the Bay. An increase in concentration occurs on March 7, during a wet period. Concentrations drop, however, during the wet season.

Concentrations of ammonia are high on March 7, and increase through the wet season to a large peak in October. Wet periods appear to result in an increase of ammonia. Organic nitrogen values increase during April and early May, which coincides with a reported algal bloom. Bay nitrogen (ammonia, organic, and nitrate) concentrations are in approximately the same range during 1979 as in 1977 and 1978, based on HCEPC data.

Concentrations of ammonia and nitrate are typically higher in the Hillsborough River than in the Bay, while concentrations of organic nitrogen are usually lower. It might then be expected that wet weather would increase ammonia and nitrate in the Bay while reducing organic nitrogen. This trend is confirmed on March 7 and in October, after a period of high flow. The trend does not occur on May 30 or during the summer wet season. During these summer periods, when algal activity is most significant, the nitrogen cycling may be dominated by algal rather than wet weather influences.

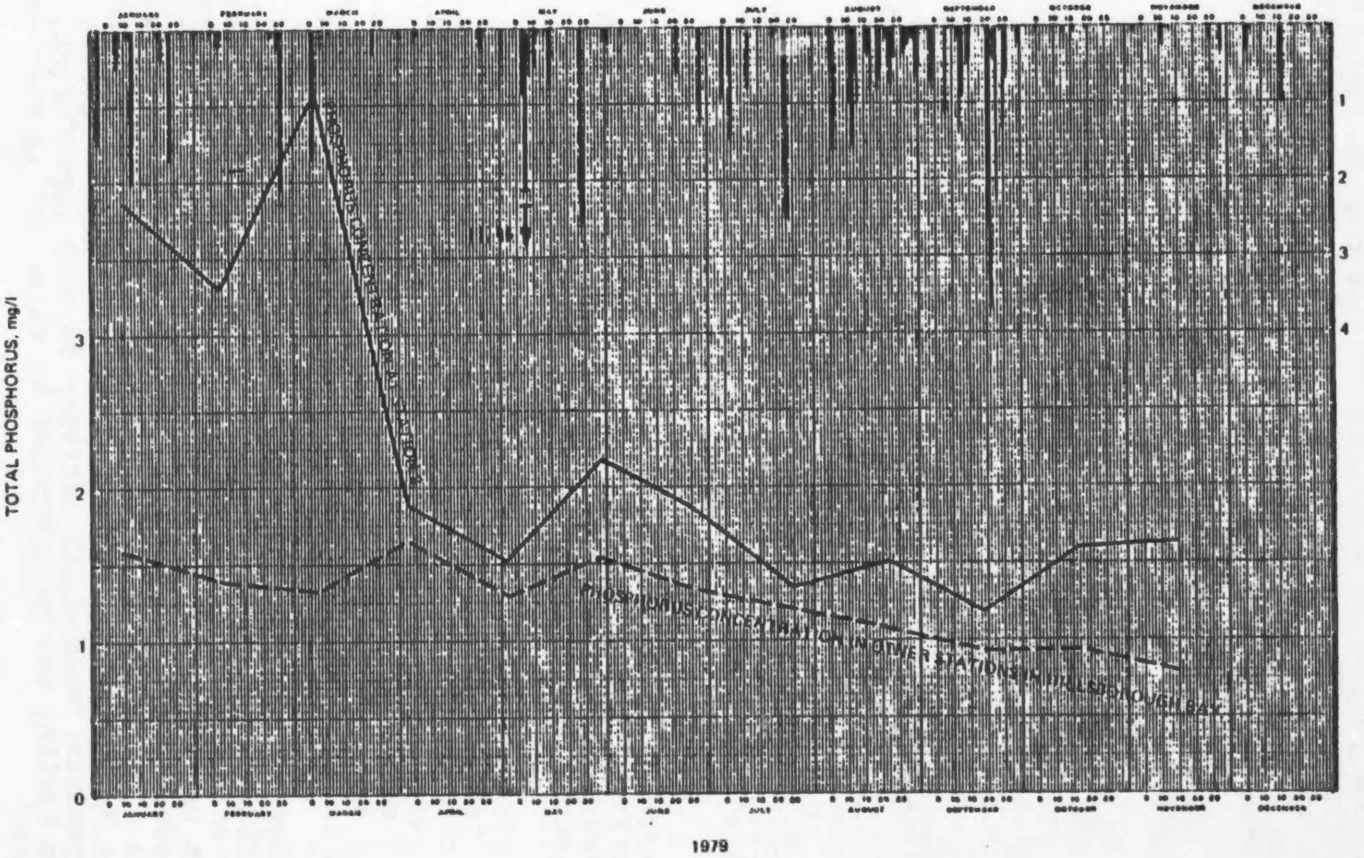

FIG. 2-13 TOTAL PHOSPHORUS CONCENTRATIONS – HILLSBOROUGH BAY, 1979

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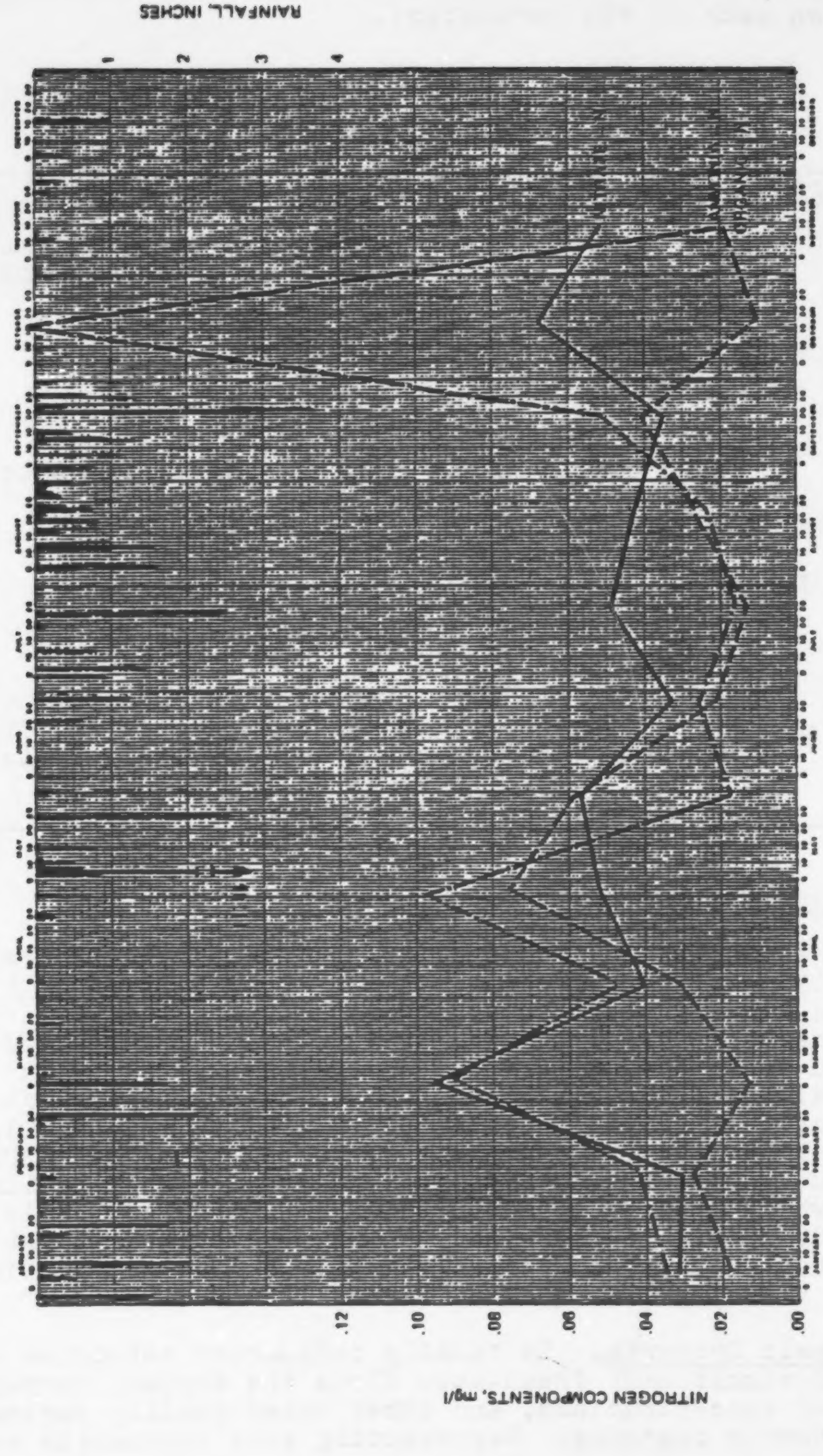

FIG. 2-14 NITROGEN CONCENTRATIONS – HILLSBOROUGH BAY, 1979

Table 2-2 is a summary of the apparent effect of wet weather on each of the parameters.

TABLE 2-2. WET WEATHER EFFECTS ON HILLSBOROUGH BAY

Parameter	Wet weather effects
Salinity	decreases concentrations, but increases horizontal and vertical variations
Flushing Time	decreases
DO	decreases
BOD	increases after large storms
Solids & Turbidity	decreases
Coliform Bacteria	increases
Phosphorus	no apparent change
Nitrogen	increases in ammonia and nitrate, decreases in organic nitrogen, unless algal activity is significant

Model Assessment

The purpose of this section is to evaluate several previously developed mathematical models of Hillsborough Bay and Tampa Bay for possible application during the NURP study. First, the basic criteria necessary for modeling the effects of tides and stormwater discharges on the Bay are set forth. Additional criteria that are likely to be required to study the various aspects of water quality in the Bay are also outlined. The selection of these criteria are based on the data analysis presented in the previous section. Next, several modeling efforts which have been conducted in the Bay are briefly described. Finally, these models are evaluated in light of the established criteria to determine their future application in studying various water quality issues in the Bay.

Basic Criteria. In tidally influenced estuaries and bays with significant freshwater flows the depths, currents, salt water concentrations, and other water quality parameters are constantly changing. Representing such constantly varying conditions requires models that are time variable in nature. In addition, a dynamic model is essential because only such a model takes into account the tidal and frictional forces which determine variations of depths, velocities, and flows from one point to another. The intermittent and variable nature of stormwater discharges also requires that a time variable model be used. A steady-state approach with constant loadings cannot reproduce the tidal variations and the storm-to-storm variations in flows and loads.

It was demonstrated during the analysis of water quality data that sufficient vertical mixing exists in Hillsborough Bay to allow modeling of the Bay as a vertically averaged system, even during wet weather. However, the horizontal variations were significant and can only be accounted for by using a two dimensional modeling approach.

Thus the basic criteria for modeling the Hillsborough Bay are: time varying, dynamic, and two dimensional computational capability.

Additional Criteria. For the purposes of the NURP study, the whole of Tampa Bay will be modeled rather than Hillsborough Bay. As shown in Figure 2-5, wet weather input from the Hillsborough River appears to affect the pollutant concentrations at the mouth of Hillsborough Bay. Because the Hillsborough Bay boundary conditions are affected by stormwater discharges it would be necessary either to accurately specify water quality boundary conditions or remove the boundary further downstream so that specified boundary conditions would not change results of the model. It would be difficult to predict and measure the water quality boundary conditions because these conditions would vary from storm to storm. Accurately prescribing the boundary condition of Hillsborough Bay would not be possible without an extensive field measurement program under a range of wet weather conditions. Therefore, in order to remove boundary effects from the simulation results, a model of Hillsborough Bay would have to include the whole of Tampa Bay, with an ocean boundary prescribed at the Gulf of Mexico. This would remove the ocean boundary as far as reasonably possible from Hillsborough Bay.

It must be emphasized that hydrodynamics are key aspects of mathematical water quality models of tidal estuaries and bays. If the movement of water is properly simulated, a firm basis for confidence in the water quality simulations is developed because transport is directly dependent on water motion. In addition, the hydrodynamic processes are well understood and therefore can be represented with reasonable accuracy by a model.

Features which are important to the hydrodynamics of the Bay are tides, inflows, shipping channels, and changes of the configuration including circulation cuts and spoil islands. The tides are the major driving force for the currents in the Bay. Freshwater inflows result in net transport out of the Bay and are therefore important. Certain large inflows, such as the TECO intake and discharge, may modify circulation patterns in the Bay. The channels, cuts, and islands are all bathymetric features which must be accounted for in the model. Because these features need to be accounted for, and because the whole of Tampa Bay would have to be modeled, the selected model should have a grid size small enough to account for the necessary physical features, but large enough so that simulation costs would be reasonable. This could be accomplished by selecting a model which has the capability to use variable size grids for mathematical representation of the physical system.

The time frame to model the Bay in regard to stormwater inputs depends on the Bay flushing characteristics and the pollutants to be modeled. Based on flushing calculations, flushing times were estimated to be on the order of a month. Therefore, fairly long simulations may be needed to simulate pollutants and their impact on the Bay. To accomplish these long-term simulations it would be necessary to select a model that would have a reasonable cost per model run.

Dispersion is also expected to be a key factor in Hillsborough Bay. Dispersion is the mechanism by which the areal extent and size of a patch of dye or pollutant increases with time. Dispersion of wastewater effluents and pollutants in a receiving water body is the result of vertical and horizontal velocity variations that normally occur in a flow cross- section. The magnitude of dispersion becomes larger with increased nonuniformity of velocity. In a water body with uniform density, dispersion may be calculated by using the Taylor (3) equation. Using Taylor's equation for example, the dispersion coefficient in a wide channel of 10 feet depth flowing with an average velocity of 2 ft/sec would equal about 0.0488 square miles/day.

In estuaries with salinity intrusions there exist considerable density variations and gradients due to the transition from ocean water to fresh water. These density variations and gradients considerably increase shear stresses and velocity gradients. As a result, dispersion in salinity intrusion zones are usually much larger and could be two to three orders of magnitude higher than that in a water body without salinity intrusions.

In modeling water quality in a tidal estuary there are many factors and parameters that need to be considered. Some of these factors and parameters may vary over a wide range. These variations in turn may effect the results of water quality simulations. It is, therefore, necessary to establish the impact of variations of the significant parameters by conducting a systematic parameter by parameter sensitivity analysis. Such analysis indicates which of the parameters are sensitive and cause significant changes to the water quality simulation results. It also establishes the insensitive parameters whose variations therefore can be ignored. By simulating the range of variation of the sensitive parameters, the expected range of variation of future water quality can also be established. Thus, sensitivity analysis and the capability to do such analysis becomes a significant factor in water quality modeling.

The following paragraphs describe models used in Tampa Bay. To use the models effectively during the NURP project, they must be documented and calibrated.

University of South Florida Model. Researchers at the University of South Florida have developed a hydrodynamic and water quality model of Tampa Bay(6)(7)(8). The hydrodynamic model is an extension of the Reid and Bodine storm surge model(9). The linearized, vertically integrated two-dimensional hydrodynamic equations are solved using an explicit finite difference method. Non-linear terms such as convective acceleration, wind, and coriolis force are omitted in this model. The model has a special routine to account for "internal boundary conditions" such as channels, barriers, islands, and other bathymetric features which may be smaller than the model grid size.

The USF water quality model accepts the hydrodynamic model results as input. Two separate water quality routines solving the conservation of mass equation are available. One is for coupled BOD and DO with first order decay and reaeration. The other is a routine for nutrients, which are modeled as conservative parameters.

Available hydrodynamic model calibration is a plot of simulated vs. measured tide. The model simulations indicate the presence of several rotary circulations or gyres in the Bay, which were compared with measured water temperatures(15).

The water quality model has been applied to calculate distributions of nutrients, BOD, and DO(6,11,16). Constant average yearly loadings from the major pollutant sources were input to obtain yearly average pollutant distributions in the Bay. Dispersion in the Bay has been neglected as being relatively unimportant. The simulated pollutant concentrations are dependent on the pollutant loads input, movement due to currents, and the exchange of pollutants at the boundary of Tampa Bay and the Gulf of Mexico. The simulated concentrations have also been compared to yearly average concentrations measured by HCEPC.

USGS. The USGS has developed a model(1) of Tampa Bay, using the mathematical programs of Leendertse(12), to simulate the effects of channel dredging on circulation. This application involved simulation of hydrodynamics only. A water quality analysis program is also available, but has not been used in the dredging application. Leendertse's programs require simultaneous solutions of hydro dynamics and water quality. As a result, the same computational time step must be used for water quality simulations as for hydrodynamics. This makes the model rather expensive for simulating longer term water quality conditions.

The model was calibrated with USGS tide and current data. At four stations, model results are compared with measured tides over one tidal cycle, and at three stations, results are compared with measured velocity magnitudes over a tidal cycle. Velocity direction comparisons are not presented

TECO. Stone & Webster has modeled Tampa Bay for the Tampa Electric Company to evaluate impacts of the TECO power plant discharges(5). The TECO model was based on the CAFE(13), and DISPER(14,15) programs, developed at the Massachusetts Institute of Technology. The model uses the finite element solution technique, which allows specification of variable element size in the grid. The equations of momentum, continuity and conservation of mass are solved in this model. The model may be used to simulate various parameters, including a detailed nitrogen cycle added at the University of Virginia.

Calibration of the hydrodynamics was done by comparing current amplitudes (measured by USGS in 1972) and spot current measurements taken during the TECO study. The water quality was calibrated by simulating dye concentrations resulting from a dye study. It was used to predict far-field temperature distributions resulting from the plant's thermal discharge.

Hagen. This model (also known as the DECS model) was developed for the Federal Water Pollution Control Administration and it was adapted for two-dimensional computations for use on Hillsborough Bay. In the Hillsborough Bay study(17), known as the Hagen report, the model was used to analyze the chloride distribution in the Bay. A solution of the conservation of mass equation is performed. The momentum equations are not solved, so transport is approximated in the model by using empirical "dispersion coefficients".

ESTRY. This steady-state model was used in 1976 for the Florida State Department of Environmental Regulation(17) to determine waste load allocations to receiving waters. Wasteloads were developed for estuaries and bays in the Tampa area under steady-state conditions. This model is essentially a Streeter-Phelps type model suitable for application in streams and rivers with near constant flows.

Model Selection. To summarize, the basic and additional criteria established as necessary for modeling Hillsborough Bay water quality conditions are presented in Table 2-3. Each of the five models mentioned above are first rated against the basic criteria. Models that satisfied the basic water quality criteria are further evaluated in terms of their capability to model the additional needs of the water quality analysis.

As can be seen from Table 2-3 the Hagen model and the ESTRY model developed by the Florida DER are eliminated from further consideration, because they do not meet all of the basic water quality analysis criteria.

Two of the remaining three models are able to reproduce important physical features in various ways. The USF model uses the "internal boundary conditions" and the TECO model has a variable size finite element grid. The USGS model can account for the features only by decreasing the constant grid size to the size of the smallest desired feature. If the grid size is reduced the number of grids would increase resulting in higher cost for simulation. Thus, a trade-off must be made between increasing the cost of simulations, or reducing the resolution of bathymetric features.

TABLE 2-3. MODEL ASSESSMENT
OF HILLSBOROUGH BAY[1]

	Model identification				
Basic criteria	USF	TECO	USGS	Hagen	ESTRY
Time variable	X	X	X	X	
Dynamic	X	X	X		
Two-dimensional	X	X	X	X	X

	Model identification		
Additional criteria	USF	TECO	USGS
Method to simulate physical features	X	X	
Sensitivity analysis of hydrodynamic terms		X	X
Sensitivity analysis of dispersion		X	X
Time variable loadings		X	X
Cost of long-term simulations	X	X	
Documentation		X	X
Hydrodynamic calibration			X
Water quality calibration			X

---

1. An X indicates information is available to show that the model is applicable for the stated criteria.

In the USGS model water quality equations are coupled to the hydrodynamic equation. Therefore, both hydrodynamic and water quality programs must be run together at the same time. As a result, costs of using this model to perform long-term simulations may be excessive.

At present, the TECO model appears to be the most applicable to the Hillsborough Bay. The USF model could not be applied with confidence until the following investigations were carried out:

1. A sensitivity analysis to determine the impact of the non-linear hydrodynamic terms which are omitted in the USF model.
2. A sensitivity analysis to determine the impact of dispersion in Hillsborough Bay under wet weather conditions.
3. Modification of the model to include time variable pollutant loadings.
4. A thorough evaluation of the model documentation, and its calibration and verification procedure.

Additional calibration may also be necessary for whichever model is finally selected for use in Hillsborough Bay.

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APPENDIX A

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TABLE A-1. VALUES OF STANDARD DEVIATIONS FOR WATER QUALITY PARAMETERS

Parameter	Reference figure	1979 sampling dates[1]											
		Jan. 10	Feb. 8	Mar. 7	Apr. 4	May 2	May 30	June 27	July 25	Aug. 22	Sept. 19	Oct. 17	Nov. 14
Dissolved Oxygen, mg/l													
Surface	2-6	0.8	1.5	2.9	0.8	1.1	2.3	1.4	1.9	3.0	1.7	1.1	1.1
Bottom	2-6	1.0	1.0	2.3	0.8	1.8	2.9	1.7	1.5	1.5	1.8	1.5	1.5
BOD$_5$, mg/l	2-8	1.2	2.4	2.7	0.8	2.0	2.3	1.2	1.8	1.1	0.9	0.5	0.8
Suspended Solids, mg/l	2-10	11.8	10.0	12.3	22.3	29.9	31.3	8.1	24.6	17.9	12.4	12.4	30.0
Turbidity, NTU	2-10	2.2	1.8	2.2	4.3	9.45	6.6	2.1	2.4	1.7	1.0	1.8	4.3
Phosphorus, mg/l	2-13	0.4	0.2	0.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1
Organic Nitrogen, mg/l	2-14	.03	.02	.05	.03	.06	.05	.05	.02	.04	.07	.09	.05
Ammonia-Nitrogen, mg/l	2-14	.02	.01	.01	.02	.05	.03	.05	.001	.01	.02	.00	.01
Nitrate-Nitrogen, mg/l	2-14	.04	.03	.06	.04	.02	.03	.01	.03	.05	.03	.04	.04

1. Data collected by Hillsborough County Environmental Planning Commission.

LOWER HILLSBOROUGH RIVER

General

The lower Hillsborough River, shown in Figure 3-1, extends from the City of Tampa Dam for approximately ten miles downstream to Hillsborough Bay. This portion of the River is tidally affected. The area directly tributary to the lower River comprises approximately 40 square miles of mostly urban area. The lower River also receives flow over the Tampa Dam, from Sulphur Springs and from tidal interchange with Hillsborough Bay.

Data Base Summary

The purpose of this section is to describe the source and type of existing data used in the evaluation of the lower Hillsborough River water quality.

Physical data describing the lower Hillsborough River and used in this analysis include:

1. Depth and cross-sectional data collected by the University of South Florida.
2. Flow, water surface elevation and velocity data collected by the USGS and the City of Tampa.
3. Rainfall data collected by the U.S. Weather Bureau.

Detailed cross-sectional information has been collected by the University of South Florida for 61 cross sections from the Tampa Dam to Hillsborough Bay. The distance between cross sections are approximately 1,000 feet for the first seven miles below the Tampa Dam and are approximately 500 feet apart for the three miles closest to the Bay. A cross-section of the River based on these data is shown in Figure 3-2. The USGS gages flow at the Tampa Dam and at Sulphur Springs, and measures tidal heights in Hillsborough Bay.

In the lower Hillsborough River, the water quality data reviewed include:

1. Data collected by the City of Tampa from March 1978 to June 1980.
2. Data collected by the Hillsborough County Environmental Protection Commission from January 1972 to July 1980.

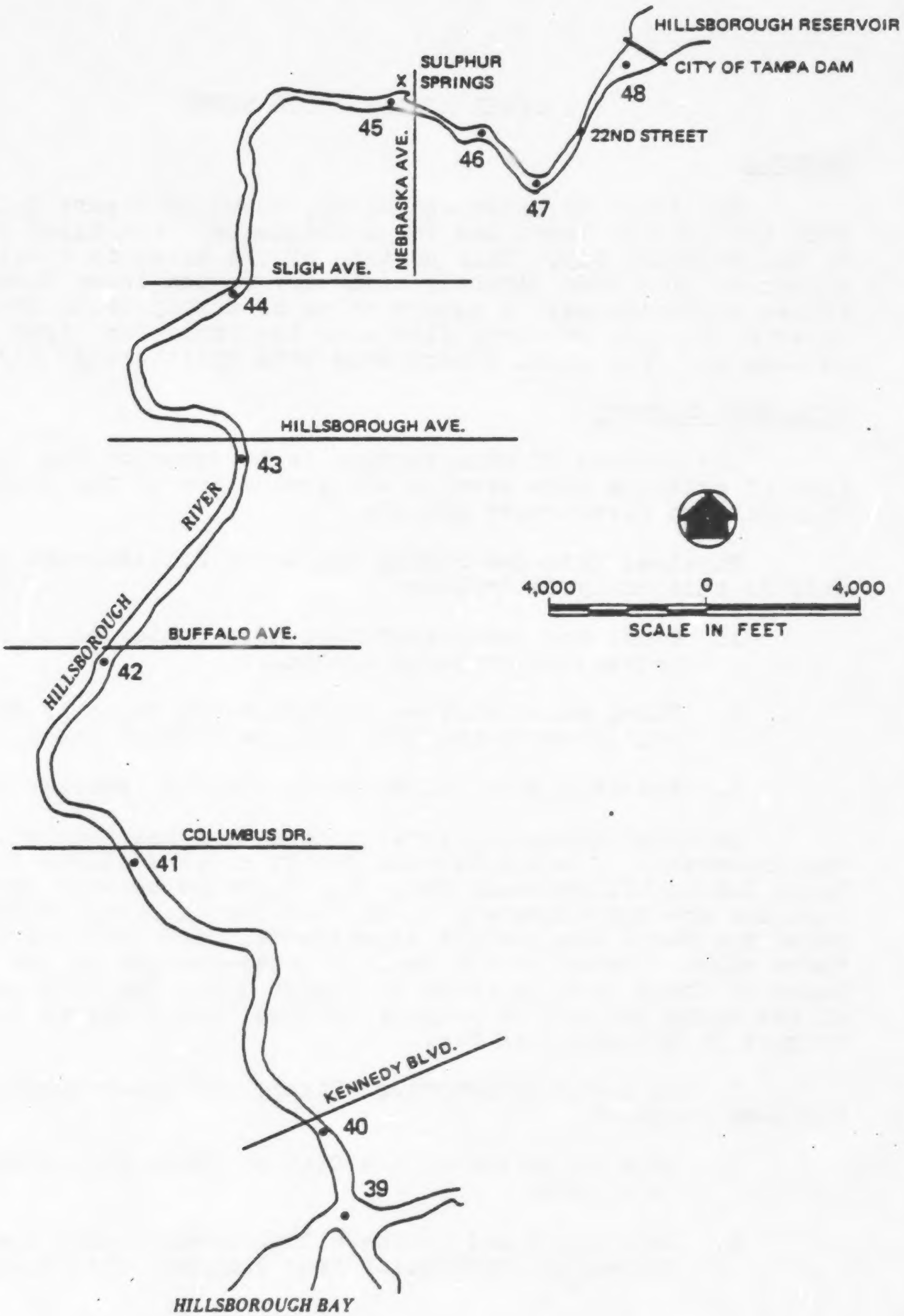
HILLSBOROUGH RESERVOIR
CITY OF TAMPA DAM
48
SULPHUR SPRINGS
X
22ND STREET
45
46
47
NEBRASKA AVE.
SLIGH AVE.
44
HILLSBOROUGH AVE.
43
HILLSBOROUGH RIVER
4,000
0
4,000
SCALE IN FEET
BUFFALO AVE.
42
COLUMBUS DR.
41
KENNEDY BLVD.
40
39
HILLSBOROUGH BAY

FIG. 3-1 PLAN OF LOWER HILLSBOROUGH RIVER SHOWING SAMPLING LOCATIONS

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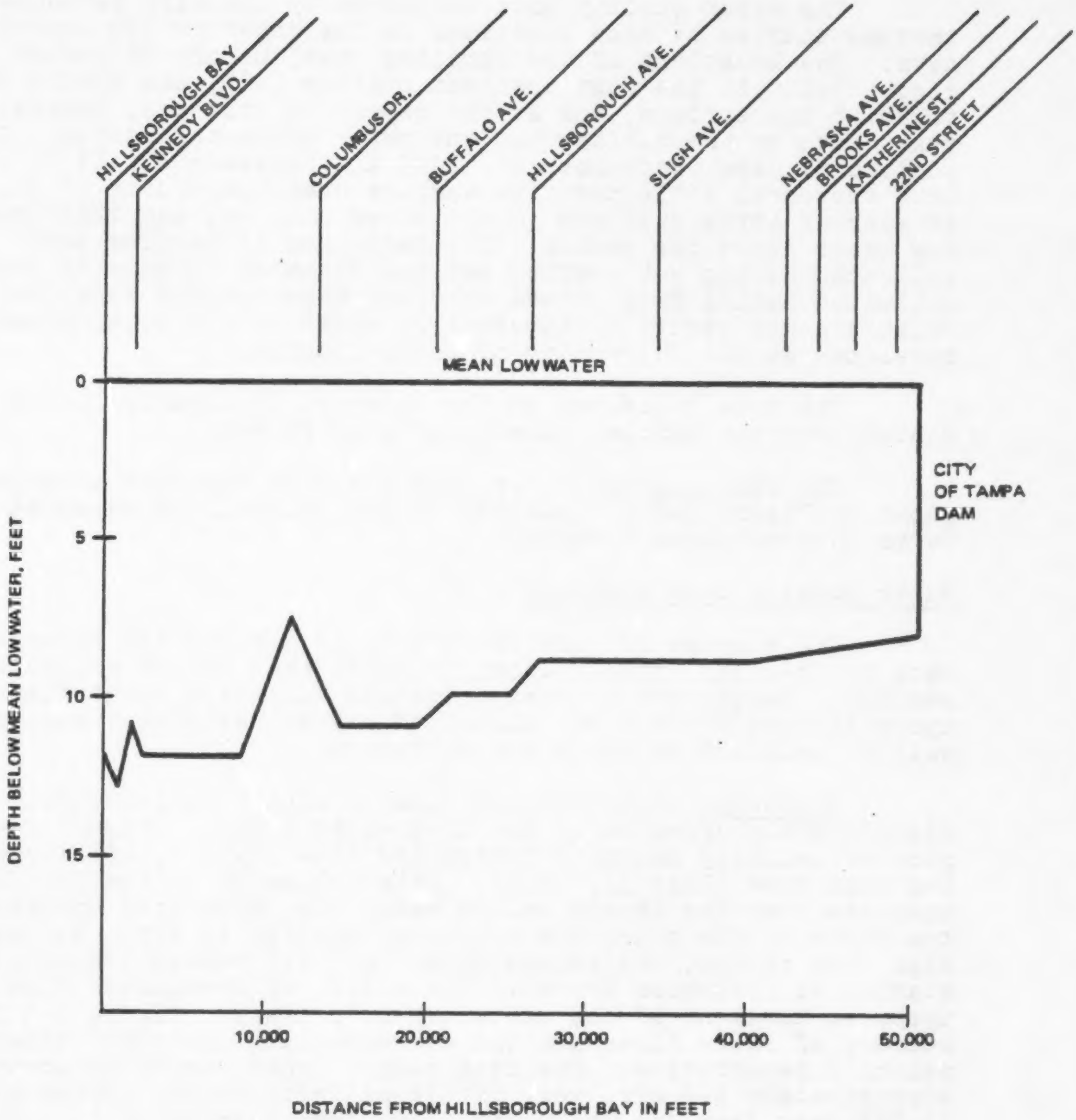

SOURCE: UNIVERSITY OF SOUTH FLORIDA, CENTER FOR MATHEMATICAL MODELS

FIG. 3-2 BOTTOM PROFILE OF LOWER HILLSBOROUGH RIVER

The water quality data collected by the City personnel include samples at nine locations in the River on ten separate days. The locations of the sampling stations are presented in Figure 3-1. At the most upstream station (48), one sample was taken at the surface, and at the remaining stations, samples were taken both at the surface and one meter above the bottom. On two additional days (September 24, 1979 and December 13, 1979) the City personnel collected five samples over the course of the day at each of three stations in the River (40, 44, and 22nd Street) one meter above the bottom. The September 24 samples were collected during wet weather and the December 13 samples were collected during dry. These synoptic measurements were used to calibrate and verify a mathematical model of the lower River developed at the University of South Florida.

The data collected in the River by the County include monthly surface samples taken near 22nd Street.

The sampling dates for 1979 and 1980 for both programs are shown in Figure 3-3 in relation to the rainfall as measured at Tampa International Airport.

Water Quality Data Analysis

The purpose of this section is to analyze the water quality data to identify water quality problems that may be caused by wet weather. Parameters discussed include salinity, stratification, hydraulic residence time, dissolved oxygen resources, suspended solids, coliform bacteria and nutrients.

Salinity. Hillsborough River salinity varies widely and is significantly affected by the freshwater inflow. Figure 3-4 is a plot of salinity measured during low flow (May 17, 1978) and during high flow (July 31, 1978). Data collected on the low flow day indicate that the denser saline water has penetrated upstream in the River to the point where Sulphur Springs enters. During the high flow period, the saline water has been pushed downstream of station 41 (Columbus Drive). The effect of freshwater flow on the upstream movement of the saltwater is evident. Figure 3-5 is a summary of river flows and the corresponding upstream distance of salinity penetration. The data suggest that for flows above approximately 900 cfs, very little salinity exists beyond about 12,000 feet from the Bay. For flows less than about 100 cfs, the salinity moves into the upstream area, usually up to Sulphur Springs. Between these flows is an intermediate range of partial salinity penetrations. At about 12,000 feet above the Bay, there is a rise of about 3.5 feet in the bottom profile. The depth of flow at this point is about 7.5 feet at mean low water. This rise in the River bottom appears to act as a barrier for saltwater penetration upstream. Salinity exists below this point on all the dates when observations were made.

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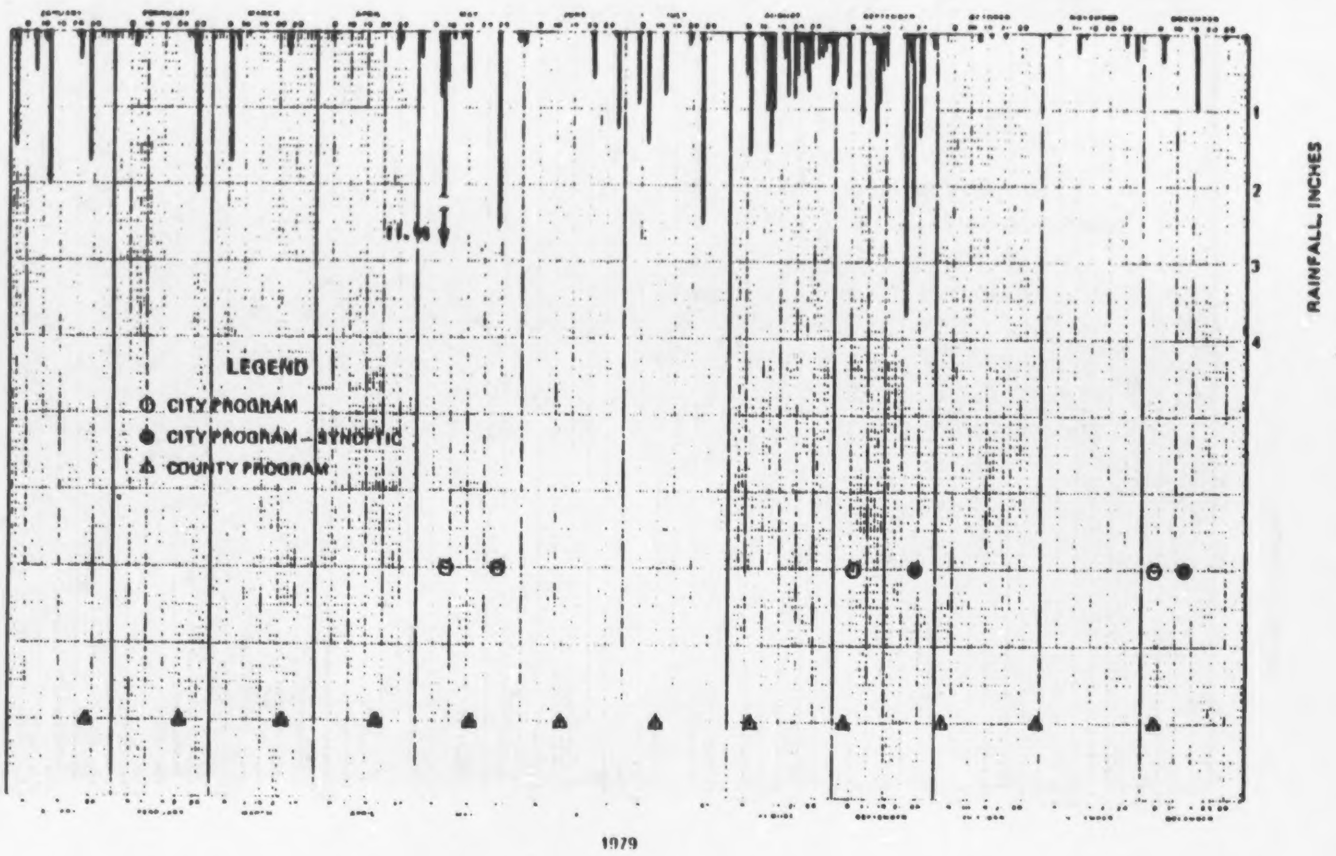


FIG. 3-3 WATER QUALITY SAMPLING DATES – HILLSBOROUGH RIVER, 1979

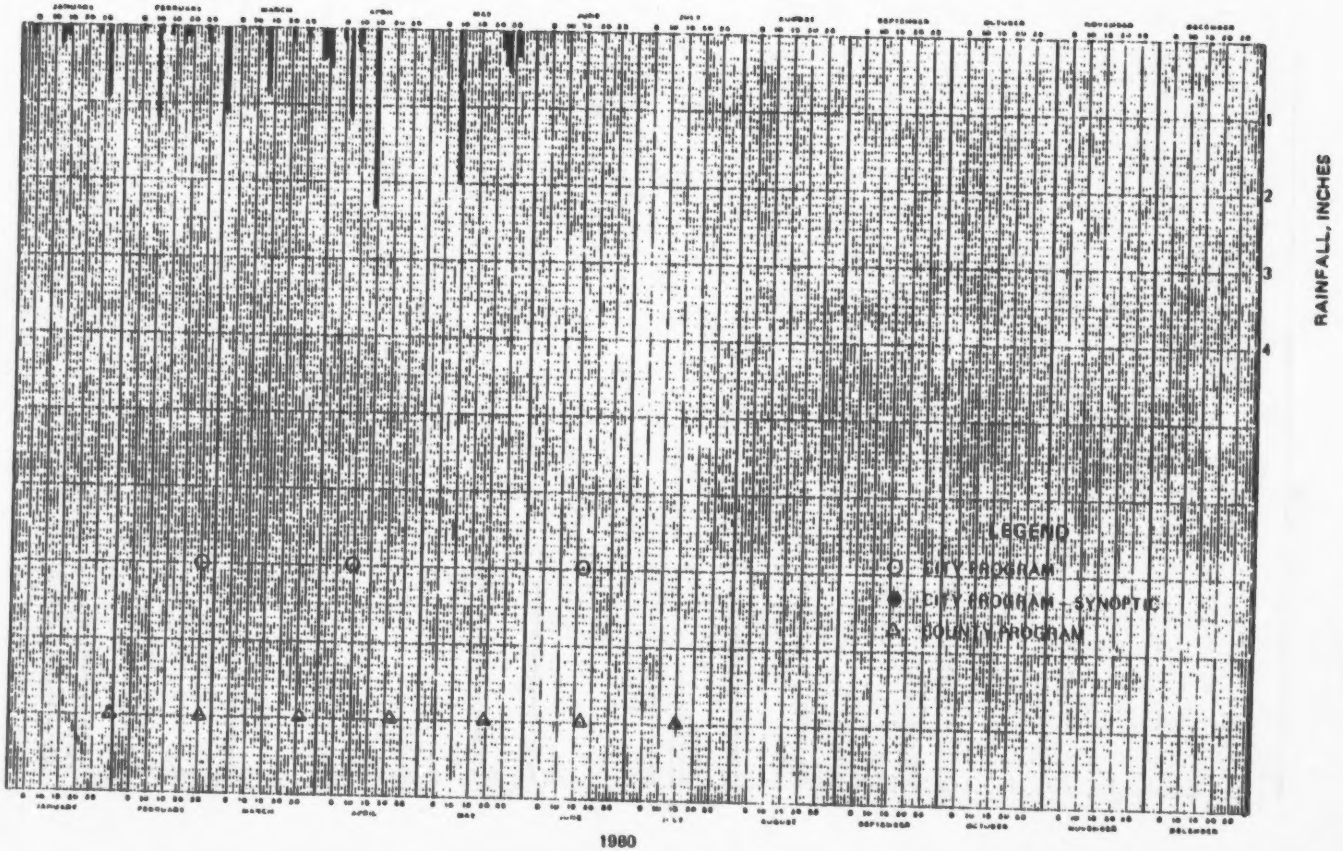
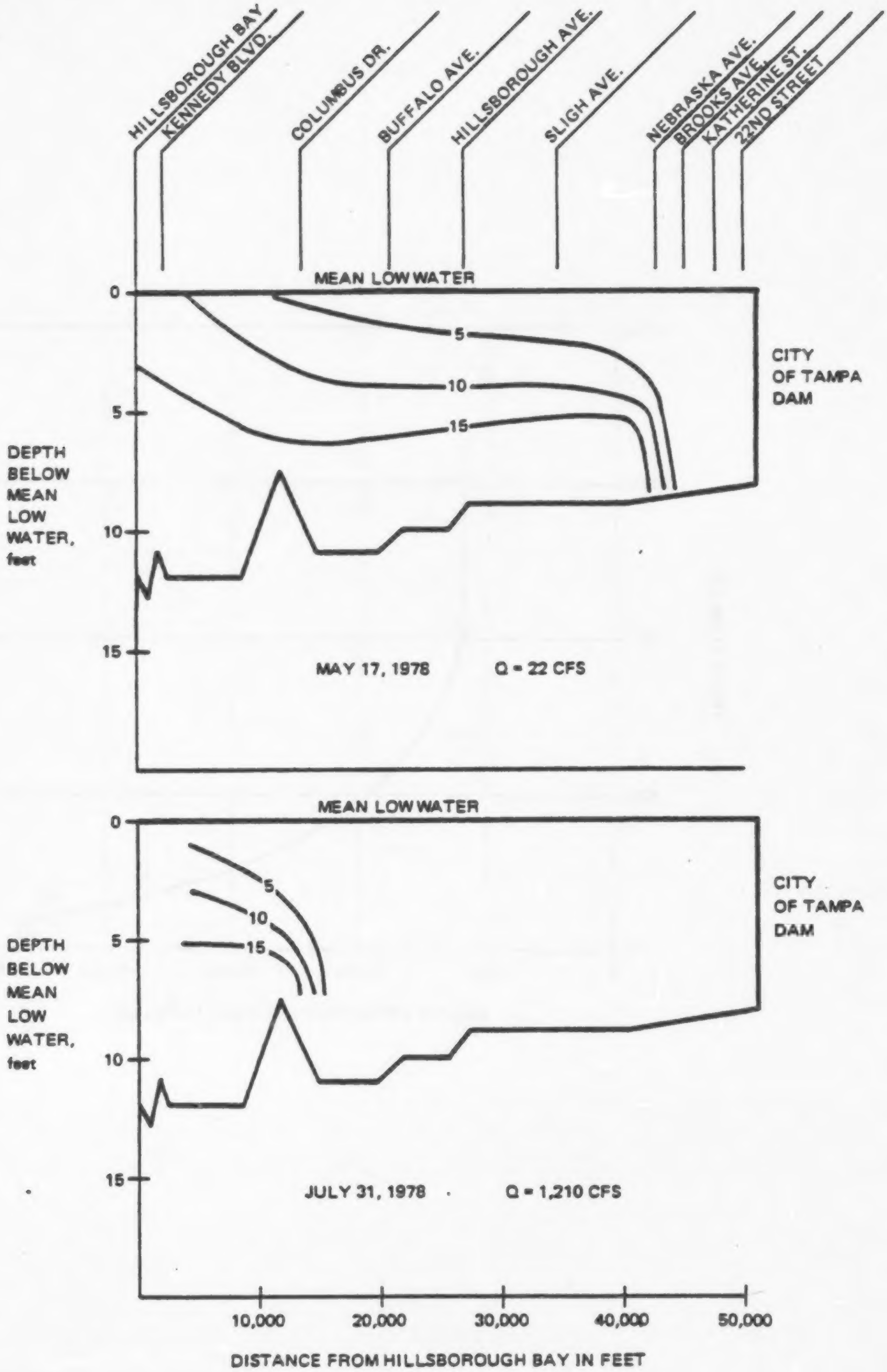


FIG. 3-3 (Continued). WATER QUALITY SAMPLING DATES – HILLSBOROUGH RIVER, 1980



NOTE: SALINITIES IN PARTS PER THOUSAND.

SOURCE: CITY OF TAMPA

FIG. 3-4 SALINITY IN THE LOWER HILLSBOROUGH RIVER

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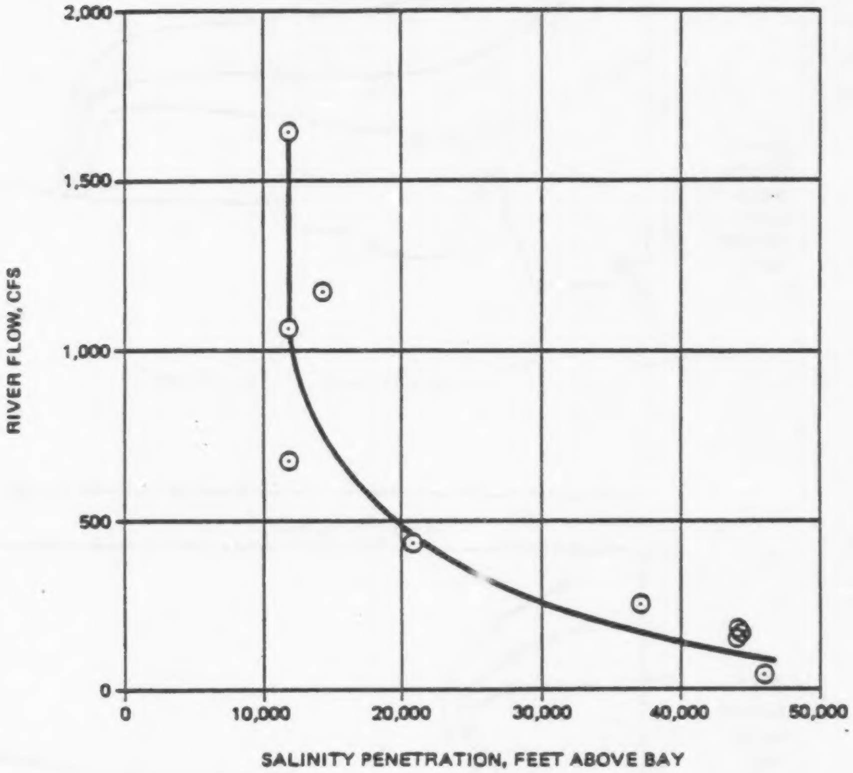


FIG. 3-5 EXTENT OF UPSTREAM SALINITY MIGRATION VS. FLOW IN THE LOWER HILLSBOROUGH RIVER

The extent of saline penetration in the lower Hillsborough River can be estimated by using the densimetric Froude number. This is defined as:

$$F_d = \frac{U_f}{\frac{[g(P_s-P_f)h]^{1/2}}{p_f}}$$

Where

F_d = densimetric Froude number

U_f = freshwater velocity

g = gravitational acceleration

p_s = density of saltwater layer

p_f = density of freshwater layer

h = depth of river at shallow point = 7.5 feet

For a Froude number larger than 1, the saline water cannot penetrate into the River. For a Froude number less than 1, the salinity can intrude upstream to varying degrees. As F_d becomes smaller, the salinity penetration can extend further. The largest or critical Froude number occurs at the point of smallest depth. This occurs at the barrier mentioned previously, which is about 12,000 feet above the Bay.

To estimate the magnitude of F_d in the Hillsborough River, velocities measured by the City of Tampa and USF (1) during low and high flow conditions are used. Assuming a salinity concentration of 15 ppt in the lower layer and 5 ppt in the upper layer, and using the critical channel depth of 7.5 feet, the following estimate is obtained:

$$F_d = \frac{U_f}{1.7}$$

The time variation of velocities at the surface on September 24 and December 13, 1979 were measured at stations 40 and 44. These values are interpolated to determine the velocities at the critical section. The maximum velocities are used so that the largest Froude numbers are obtained. For a maximum velocity of about 2.3 fps on September 24 and about 0.40 fps on December 13, the corresponding F_d's are 1.4 and 0.24. Since F_d on September 24 is greater than 1.0, no saltwater above the critical section is anticipated under this condition. Since Fd on December 13 is less than 1.0, saltwater penetration is anticipated under this condition. Salinity measurements taken on both dates confirm these calculations.

Stratification. The potential for stratification of the Hillsborough River can be estimated using the stratification parameter developed by Thatcher, et. al. (2). This parameter (G/J) is a ratio of the stratifying forces to mixing forces in an estuary. The parameter is linearly related to a readily definable parameter known as the estuary number, defined as follows:

$$E_d = \frac{P_T F_d^2}{Q_f T}$$

Where

E_d = estuary number

P_T = tidal prism

F_d = densimetric Froude number

Q_f = freshwater flow

T = tidal period

For the September 24 and December 13, 1979 measurements, the estuary numbers, and thus stratification parameters, are calculated as follows:

Date	Flow, cfs	Froude No. F_d	Estuary No. E_d	Stratification Parameter G/J
9/24/79	2,300	1.4	0.50	310
12/13/79	110	0.24	0.19	120

Based on tests by Ippen and Harleman (3), the stratification parameter of 310 during high flow indicates completely mixed conditions. The stratification parameter of 120 during the low flow condition indicates partial stratification. Complete stratification occurs at a value of less than about 20. Thus, calculated stratification parameter values appear to be in line with expected conditions based on salinity data. During high flow, there is no saltwater in the River and thus no stratification. During low flow, there is saltwater; but it appears to be partially mixed.

Salinity measurements were taken by the City in the Hillsborough River at the surface and 1 meter above the bottom. No continuous vertical profiles of salinity are available over a range of flow conditions. Vertical profiles of salinity would confirm judgments made on the amount of mixing which occurs in the estuary during low flow. Two conditions are possible, the first being a partially mixed system. In a partially mixed system, there is vertical mixing despite a large vertical salinity difference. The second type of system is stratified, in which two distinct layers are formed, and mixing between the layers is limited. The distinction between these two types of systems is important in terms of representing the system mathematically. The stratified system would be more difficult to model because the layer interface location, and the transport between the layers would have to be accounted for. For partially mixed conditions, an assumption that the system is one-dimensional (cross-sectional averaged), would be adequate. Recent data collected on one day (July 11, 1980) by the USF indicates that a partially mixed condition and not a two-layered condition exists in the Lower River under low flow conditions of approximately 100 cfs. This information strongly points toward partially mixed condtions, but should be confirmed by measurements taken on additional dates.

Hydraulic Residence Time. Estimates of the hydraulic residence time of the lower Hillsborough River are as follows:

Date	Flow condition	Flow, cfs	Hydraulic residence time, days (1)
9/24/79	High flow	2,290	0.8
2/26/80	Intermediate flow	260	6.9
12/13/80	Low flow	108	16.7

1. Calculated as River volume at mid-tide divided by flow.

The dates selected represent a range of flow conditions typically encountered in the River. The calculated values give an indication of the effect of wet weather on hydraulic residence time, and of the time scale needed to model the river. The condition which is most likely to be of interest during the NURP study is that of intermediate flow, and may represent a storm superimposed on a low flow condition. The hydraulic residence time for this condition is about one week.

The method used to calculate the hydraulic residence time gives conservative (high) values. It is implicitly assumed that the flow has the entire volume available for treatment. This may not be true, particularly at lower flows. In addition, tidal flushing has not been considered in the analysis, which may result in shorter residence times.

Dissolved Oxygen Resources. The dissolved oxygen concentrations measured since 1978 by the City of Tampa and the

Hillsborough County personnel in the lower Hillsborough River show widely varying ranges from zero to above saturation. Several trends can be observed in the data:

1. Recorded DO concentrations below 4.0 mg/l (State standard for waters in the lower Hillsborough River) generally occur in the saltwater which intrudes into the River.

2. The lowest DO values (less than 2.0 mg/l) occur in May and June when River flows are the lowest and the penetration of salt water is the greatest.

3. Surface DO concentrations are rarely below 4.0 mg/l and values above the saturation level have been measured in May and June.

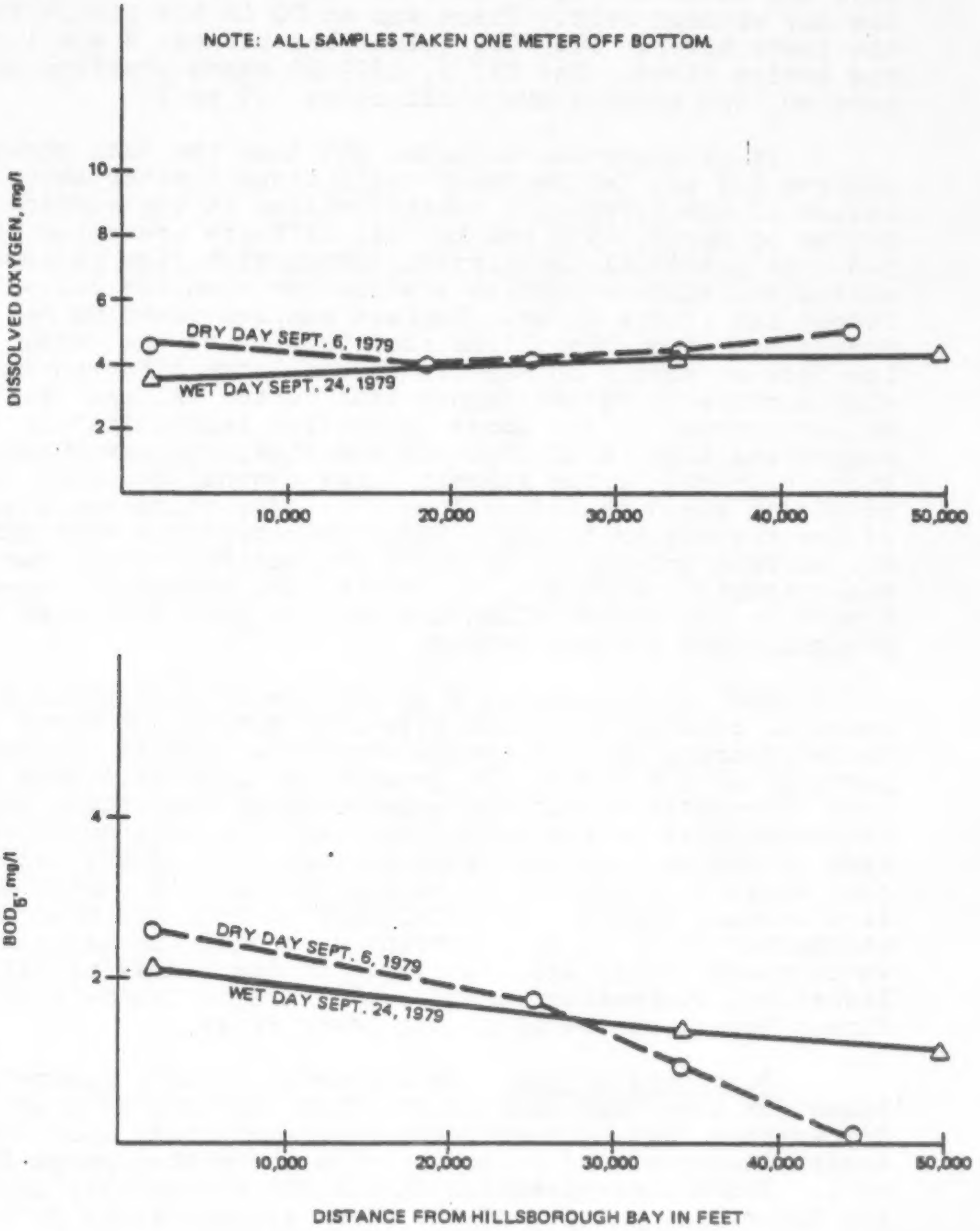
4. DO values generally decrease as one moves from the Tampa Dam downstream towards the Bay.

In order to assess the potential impact of urban runoff on the DO values in the lower River, two sets of comparisons are made. One comparison is made during wet weather when River flows are high and one during dry weather with low River flows.

Two days during wet weather were selected to compare measured DO concentrations. One day, September 6, 1979, is preceeded by two dry days, and the other day, September 24, 1979, is immediately preceeded by approximately 2.25 inches of rainfall. The DO concentrations for these two days along with the BOD_5 values, both measured one meter above the bottom, are plotted in Figure 3-6. As can be seen, there is no indication that the storm directly preceeding the September 24 date caused a change in either the DO or the BOD_5 concentrations. The measurements available for these two dates indicate that there is little or no variation with depth during periods of high flow when there is no saltwater in the River.

The BOD_5 values shown in Figure 3-6 are below 2.0 mg/l on both days for most of the River's length. These BOD_5 values are similar to the BOD_5 concentrations measured in the Reservoir and are not indicative of severely polluted waters.

Since the volume and subsequent impact of urban stormwater runoff would be proportionately greater during lower flow, a second comparison for two days during this period of the year is made. For this comparison, May 17, 1978 which is preceeded by a week of dry weather, is selected as the dry day. The wet day selected is May 9, 1979 which is preceeded by two days when over 13 inches of rain fell. Flow over the Tampa Dam was negligible on this day, because it was being diverted into the Tampa Bypass Canal. Therefore, flow in the River during this period was mainly due to urban runoff. The DO and BOD_5 values measured on these



SOURCE: CITY OF TAMPA.

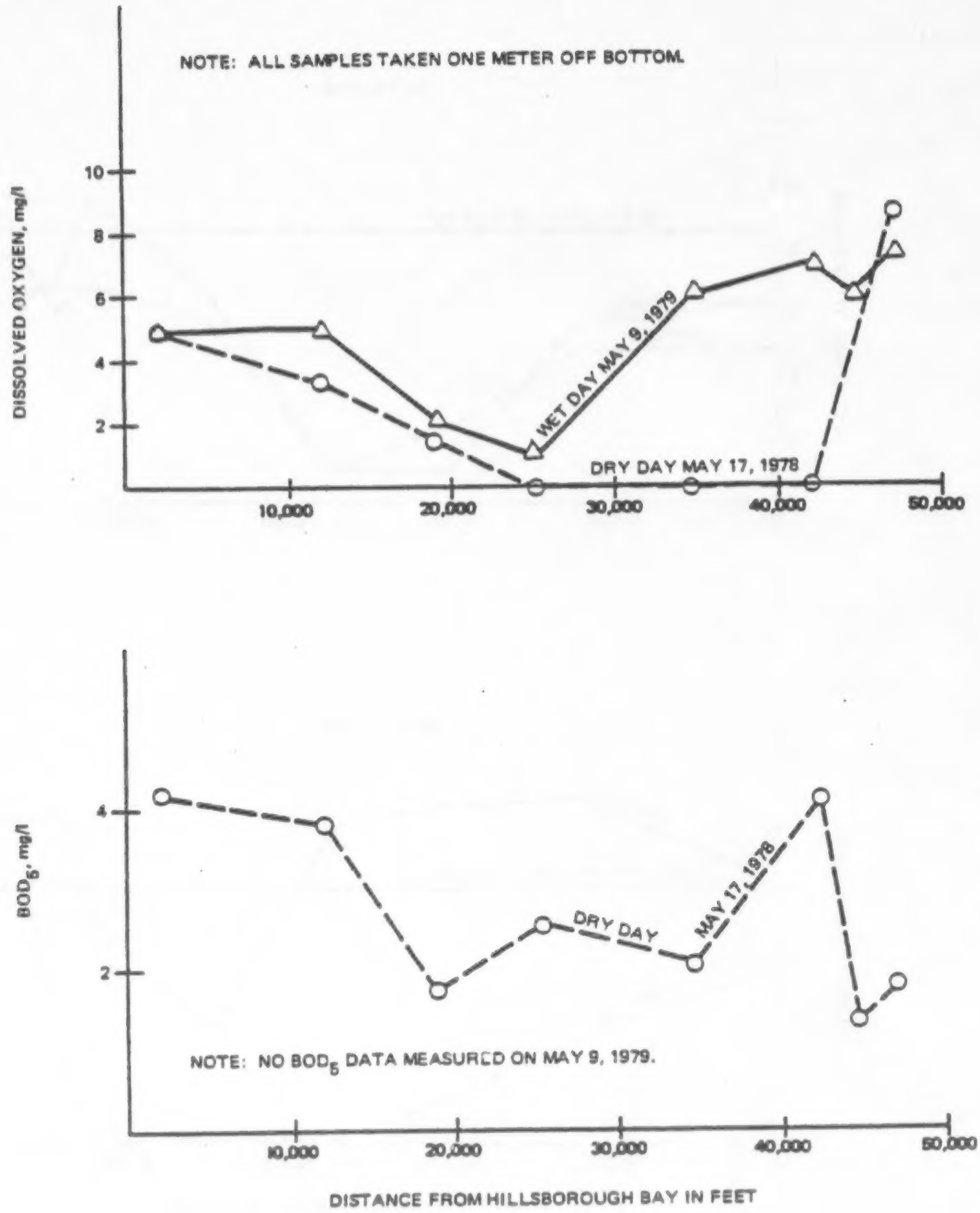
FIG. 3-6 DISSOLVED OXYGEN AND BOD_5 IN LOWER HILLSBOROUGH RIVER, WET SEASON

days are shown in Figure 3-7. DO concentrations were lowest on the day without rain. There was no DO in the middle reaches of the lower River. The BOD_5 values are between 2 and 4 mg/l through the entire river. The May 9, 1979 DO concentrations are higher, however, two samples are still below 4.0 mg/l.

It is important to point out that the data shown in Figures 3-6 and 3-7 represent conditions 1 meter above the bottom of the River. DO concentrations at the surface and bottom on May 9, 1979 and May 17, 1978 are presented in Figure 3-8. As previously mentioned, during high flow periods, the bottom and surface samples are similar when the saltwater is forced out of the River. Surface samples taken on May 9, 1979 during high flow conditions show this to be the case. For the low flow condition on May 17, 1978 a large difference exists with surface DO values higher than bottom values. Most surface DO concentrations are above saturation (approximately 8.0 mg/l), suggesting algal activity. In addition, the low DO concentrations near the bottom suggest large benthal demands. A similar condition was measured on June 17, 1980, which was also a period of low freshwater inflow. BOD_5 concentrations were similar at the surface and one meter above the bottom for all the measurements. With BOD_5 concentrations generally between 2 and 4 mg/l in the water column and DO's at zero this also suggests a significant benthic demand.

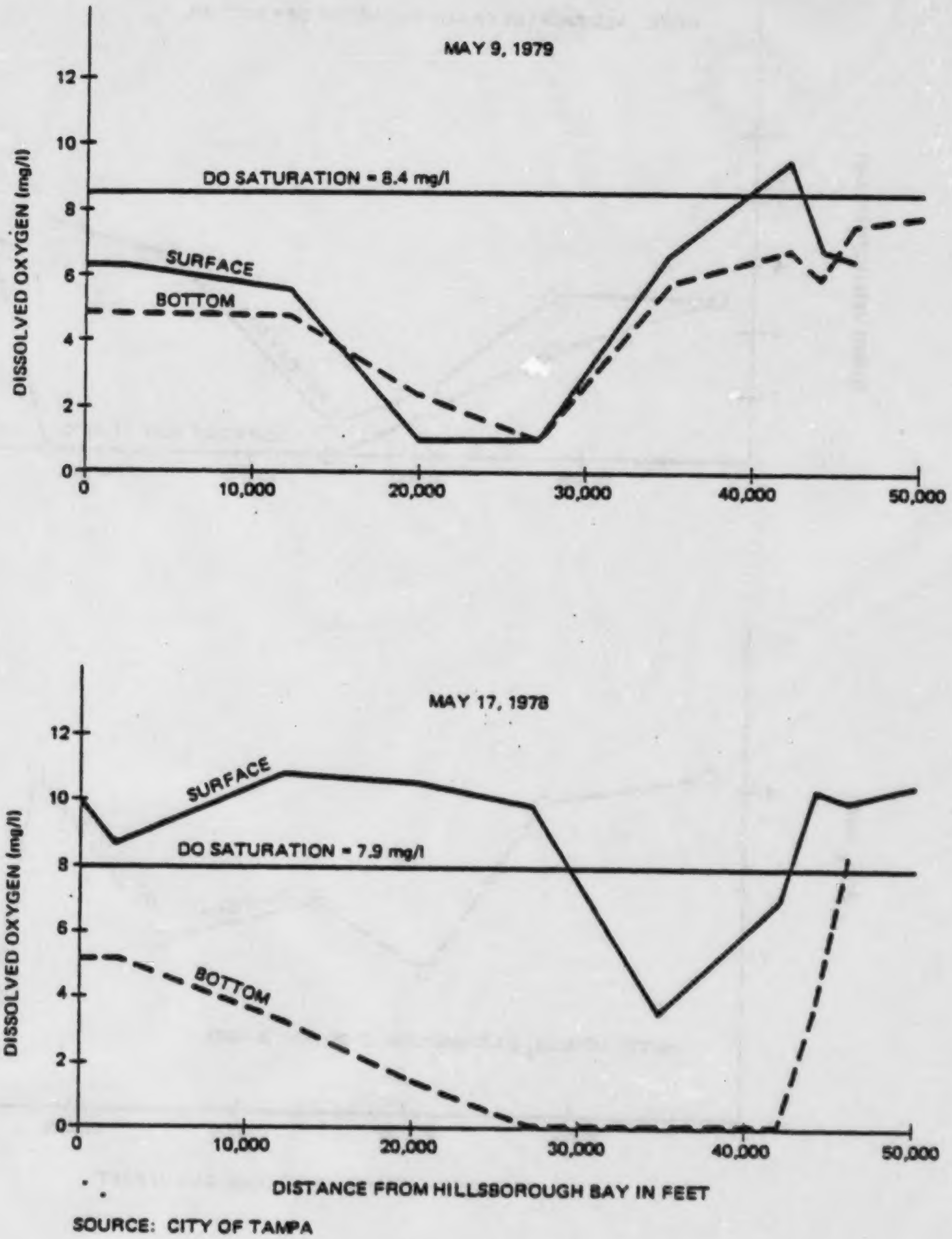
High flow conditions either due to individual storms or seasonal conditions, flush saltwater out of the River and appear to temporarily improve the DO concentrations in the bottom portions of the River. In general the available data indicate that stormwater runoff can under certain conditions improve DO concentrations in the River, and that dry weather is the worst-case condition. As mentioned earlier, one of the conditions that appears to contribute to low bottom DO's during dry periods is a benthic demand. Material carried into the River with stormwater could be an important source of the benthic deposits which subsequently deplete oxygen in the overlying waters. Therefore, stormwater runoff could have an indirect as well as a direct impact on the DO in the lower River.

Suspended Solids. Measurements of this parameter were taken for less than half of the City sampling programs. On three dry weather days, concentrations are generally less than 10 mg/l except downstream of Columbus Drive where they range from 10 to 40 mg/l. Since concentrations in the Bay are usually above 40 mg/l, the downstream portion of the River appears to be influenced by the Bay. On two wet days, suspended solids concentrations were somewhat higher for the stations upstream of Columbus Drive (5 to 35 mg/l in all but one case). Concentration variations between samples taken at the surface and one meter above the bottom were small, with the lower samples slightly higher. Wet weather may increase suspended solids concentrations in the lower River, but these concentrations are lower than in the Bay.



SOURCE: CITY OF TAMPA.

FIG. 3-7 DISSOLVED OXYGEN AND BOD$_5$ IN LOWER HILLSBOROUGH RIVER, DRY SEASON



SOURCE: CITY OF TAMPA

FIG. 3-8 DISSOLVED OXYGEN IN LOWER HILLSBOROUGH RIVER

Coliform Bacteria. The data on fecal coliform bacteria collected in the lower Hillsborough River by the City and County over the past several years generally show concentrations within state standards during periods not affected by rainfall and concentrations higher than standards for periods directly after rainfall. In summary:

1. Measured dry day fecal coliform counts are generally less than 2400 MPN/100 ml.

2. The fecal coliform counts measured after a rainfall exceeded 100,000 MPN/100 ml at stations near Hillsborough Bay with decreasing counts upstream toward the Dam.

In order to illustrate the above trend comparisons are made for fecal coliform as were previously made for DO. All fecal coliform concentrations represent surface samples. Fecal coliform data are plotted in Figure 3-9 for two September days during high flow periods and for two days during low flow periods. One of the dates during each period is directly preceeded by a rainfall, and one is not. During the high flow period directly after a rainfall, the fecal coliform counts are about an order of magnitude higher than those measured during a dry day. This occurs at all locations except at the upstream station near the Tampa Dam. This suggests that the rainfall may have had little effect on the coliform entering the lower River from upstream over the Dam, and that the increase in coliform counts were probably due to sources along the River.

Similar conditions occurred during the dry season samples with an even larger difference (3 orders of magnitude) between the rainy and dry days. The upstream station closest to the Dam also reflects the lowest values during the rainy day again suggesting that the sources of coliform are along the River. The low fecal coliform counts measured in the Reservoir just above the Dam also support this conclusion. It is important to point out that during much of the time when data were collected in the lower River there were reported sanitary sewer overflows. These, along with stormwater runoff, are the two probable sources along the River contributing to the high wet weather coliform counts.

Nutrients. The nutrients measured in the City and County sampling programs are phosphorus and nitrogen. Samples of phosphate, the inorganic form of phosphorus, collected over the past several years show the following general trends.

1. When flows are high, phosphate concentrations range from approximately 0.3 to 0.5 mg/l and are well mixed in the water column. For about the last 2 miles above the Bay, bottom concentrations increase to about 1.0 to 1.5 mg/l in the area where the saltwater in the Bay penetrates into the River.

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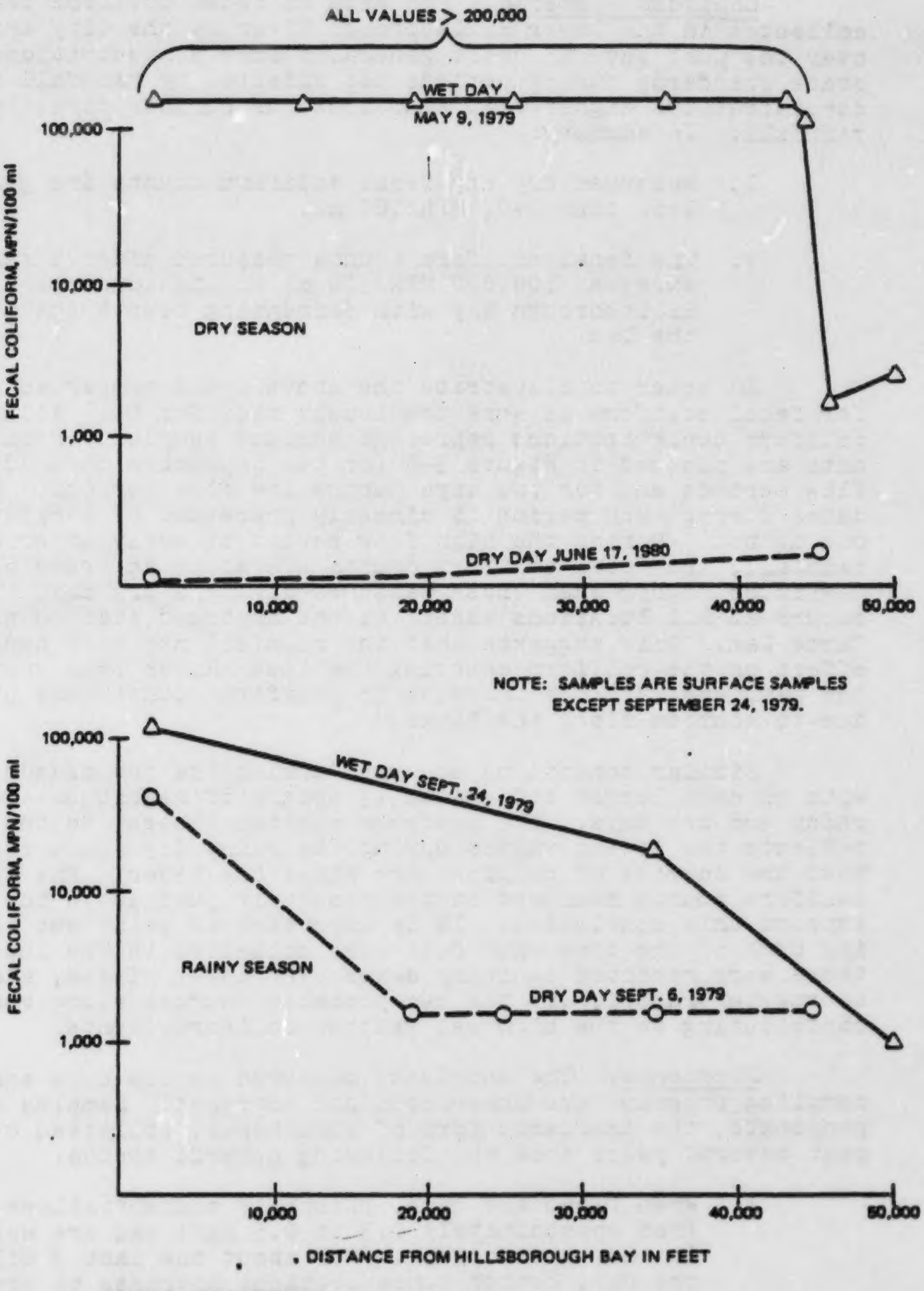

SOURCE: CITY OF TAMPA

FIG. 3-9 FECAL COLIFORM IN THE LOWER HILLSBOROUGH RIVER

2. During low flows, slightly lower phosphate concentrations (0.2-0.4 mg/l) were measured in the surface samples and high concentrations (0.5-1.5 mg/l) were measured in the bottom samples. The penetration of the Bay water with high phosphate concentrations increases from 2 to as much as 8 miles into the lower Hillsborough River during the low flow period.

In order to assess the impact of stormwater, two days during high flow periods and two days during dry periods are plotted in Figure 3-10. During both periods, the samples immediately following a rainfall have lower phosphate concentrations. The changes in phosphate concentrations parallel those of salinity and appear to be a function of the flow of freshwater through the lower River. The data indicate that runoff increases the freshwater flows which forces the Bay waters with high phosphate concentrations out of the River. In all cases phosphate concentrations are well above levels which would limit excessive algal activity.

Inorganic nitrogen has been measured in the lower Hillsborough River by the City and County. The inorganic forms of nitrogen, primarily ammonia and nitrate, are available to algae as a nutrient source. A review of the most recent available data collected in 1979 and 1980 shows a wide range of ammonia and nitrate concentrations varying from 0.0 to 0.7 mg/l along the length of the River.

During dry weather the flow over the Tampa Dam is generally low in ammonia (less than 0.05 mg/l), and concentrations increase in the middle reaches of the lower River, especially in the samples taken one meter above the bottom. In the middle reaches, bottom ammonia concentrations are typically between 0.2 and 0.3 mg/l during low flow periods. Nitrate concentrations during dry weather fluctuate between 0.01 and 0.4 mg/l showing no apparent trend.

There is only a small amount of wet weather data available over the last several years which describe inorganic forms of nitrogen in the lower River. Available data shows lower concentrations of ammonia and nitrate than measured during dry periods and little variation in the concentrations throughout the length of the lower River. This suggests that the higher River flows may flush out these nutrients.

Summary. A summary of the apparent effects of wet weather on the parameters analyzed is presented in Table 3-1. Water quality conditions in the lower Hillsborough River are a function of the freshwater flow. During low flow periods, salinity intrudes into the River. During high flow periods, material is transported rapidly to the Bay.

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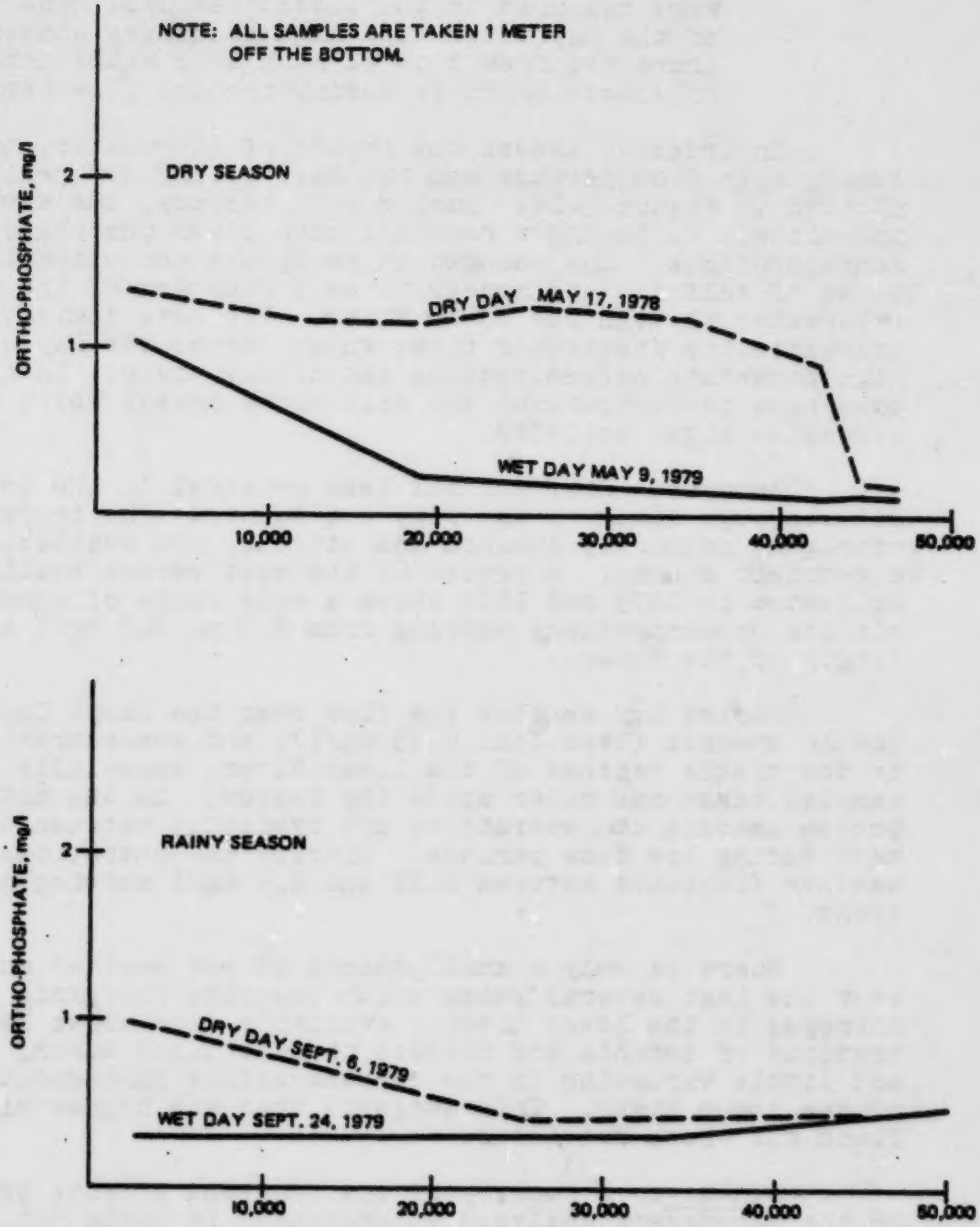
NOTE: ALL SAMPLES ARE TAKEN 1 METER OFF THE BOTTOM.

SOURCE: CITY OF TAMPA

FIG. 3-10 ORTHOPHOSPHATE IN THE LOWER HILLSBOROUGH RIVER

TABLE 3-1. WET WEATHER EFFECTS ON
THE LOWER HILLSBOROUGH RIVER

Parameter	Wet weather effects
Salinity	Decreases
Hydraulic residence time	Decreases
DO	Increases near bottom. No change or decrease near surface
BOD	No apparent change
Suspended solid	Increases
Fecal coliform	Increases several orders of magnitude
Phosphorus	Decreases near bottom. Increases near surface
Inorganic nitrogen	Decreases

During dry periods when flows are low and pollutants remain in the system longer, conditions appear to be more favorable to algal activity. Also during this period Bay waters penetrate further up the River and low DO concentrations near the bottom result. Wet weather appears to increase suspended solids concentrations slightly, and fecal coliform concentrations. Phosphorus appears to behave similarly to salinity, since a major source of both are the waters of Hillsborough Bay. Inorganic nitrogen appears to decrease during wet weather.

Model Assessment

In this section, the necessary criteria for an approach to evaluate stormwater in the lower Hillsborough River are outlined. These criteria are based upon the analysis of data in the previous section. Existing models of the River are then described. The models are then compared with the established criteria to assess their potential applicability to the NURP study.

Basic Criteria. In Chapter 2, basic criteria outlined for Hillsborough Bay included a time-varying and dynamic model. Intermittent and variable stormwater discharges coupled with tidal motion in the lower River require that a time variable and dynamic model be used in this system as well.

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Based on the discussion of salinity data, a one-dimensional model is suggested for use in the lower Hillsborough River. Preliminary analyses indicated that a partially mixed system is likely. In addition, the flow increase from stormwater input to the system would contribute to this partial mixing. A final analysis, however, must be based on vertical profile data as well as data collected before, during, and after a storm.

Additional criteria for the lower Hillsborough River model include accounting for salinity variations, dispersion, time variable loadings, documentation, and calibration of hydrodynamics and water quality.

Salinity Variations. The influence of salinity variations on circulation in an estuary is depicted in Figure 3-11. Variations in salinity result mostly from the interaction of the freshwater flow at the upstream end, tidal forces at the downstream end, and the density difference between the fresh and saltwater. The bottom waters tend to flow inward and the top waters tend to flow outward. This is also shown in Figure 3-10 by the vertical variations of velocity in the cross-section. Such circulation patterns may occur in the lower Hillsborough River during low flows. If this circulation must be accounted for, the approach needed would be to couple the hydrodynamic circulation model to a mode of salinity. The need for this type of approach must be established with more detailed data showing salinity and velocity profiles.

Dispersion. The circulation patterns shown in Figure 3-11 also affect the longitudinal dispersion of pollutants. The dispersion in the saltwater zone is greater than the dispersion in the freshwater zone because of the greater variations in the vertical velocity profile. Dispersion in the saltwater zone of the Hillsborough River can be estimated and compared to dispersion in the freshwater zone. Empirical formulas have been presented by Thatcher el al (2) as follows:

$$E_t = 77UnR_h^{5/6}$$

$$E_s = \frac{s}{x}$$

$$K = 0.002\ u_o L(E_d)^{-1/4}$$

Where

E_t = freshwater zone dispersion coefficient

E_s = saltwater zone dispersion coefficient

K = dispersion parameter

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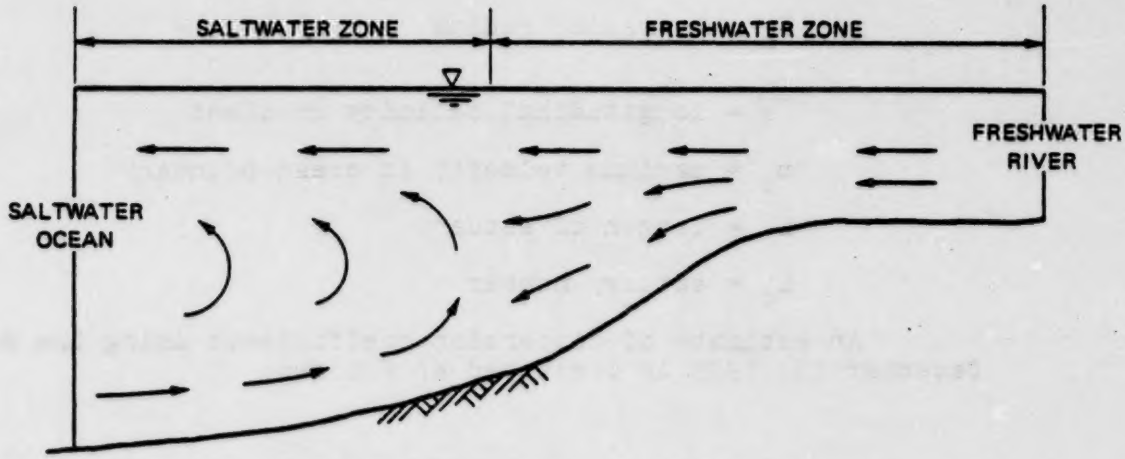
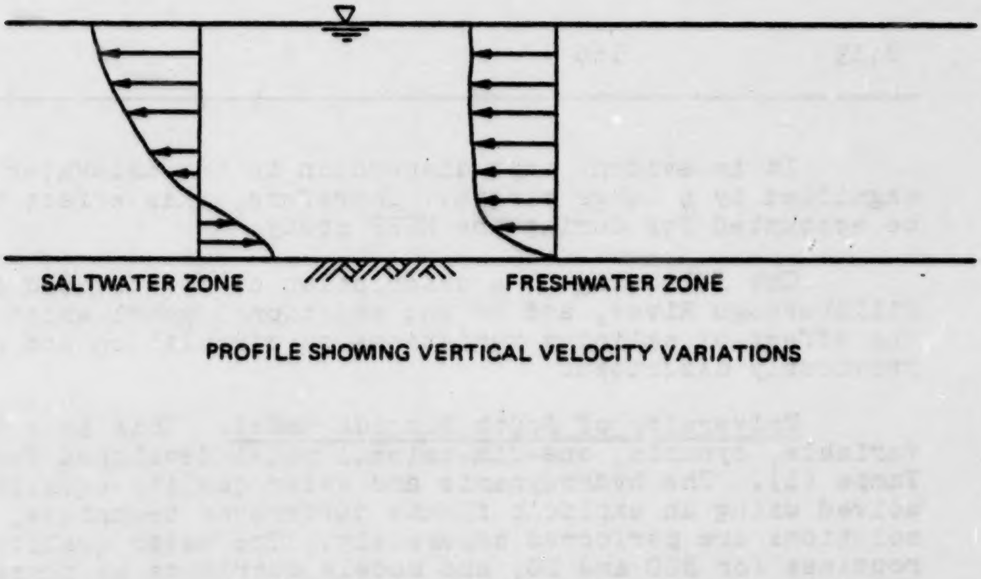

SALTWATER ZONE
FRESHWATER ZONE
FRESHWATER
RIVER
SALTWATER
OCEAN

PROFILE SHOWING ESTUARY CIRCULATION


SALTWATER ZONE
FRESHWATER ZONE

PROFILE SHOWING VERTICAL VELOCITY VARIATIONS

FIG. 3-11 CIRCULATION PATTERNS AND VERTICAL VELOCITY VARIATIONS IN AN ESTUARY

u = freshwater velocity

n = Manning's friction coefficient

R_h = hydraulic radius

$\frac{s}{x}$ = longitudinal salinity gradient

u_o = maximum velocity at ocean boundary

L = length of estuary

E_d = estuary number

An estimate of dispersion coefficients using the data of December 13, 1979 is presented as follows:

Estuary number	Dispersion parameter	Freshwater dispersion	Salinity Intrusion dispersion
E_d	K	E_t, ft^2/sec	E_s, ft^2/sec
0.19	160	6	140

It is evident that dispersion in the saltwater zone is magnified by a large margin. Therefore, this effect may need to be accounted for during the NURP study.

The following is a description of models used in the lower Hillsborough River, and of one additional model which accounts for the effect of salinity variations on circulation and dispersion as previously described.

University of South Florida Model. This is a time-variable, dynamic, one-dimensional model developed for the City of Tampa (1). The hydrodynamic and water quality equations are solved using an explicit finite difference technique, and the solutions are performed separately. The water quality model has routines for BOD and DO, and models nutrients as conservative parameters. The model does not account for the effect of salinity variations on circulation and dispersion. Dispersion is set equal to zero in the water quality model.

The hydrodynamic and water quality models were calibrated and verified using two sets of synoptic water quality data collected on September 24 (high flow) and December 13, 1979 (low flow). Verification on the low flow date indicated that the velocities were not well reproduced due to the influence of saltwater.

River. This steady-state model was used in 1976 for the Florida Department of Environmental Regulation (4). Wasteload allocations were developed for rivers in the Tampa area. It is based on the Streeter-Phelps equations of stream waste assimilation capacity.

USGS. A Hydrograph Simulation Model which produces flood hydrographs from rainfall data was used by the USGS in the Hillsborough and Alafia Rivers (5). This model was developed during a cooperative program with the Southwest Florida Water Management District. Model simulations were used to evaluate flood control plans in the river basins. It is a one-dimensional model in the sense that it simulates flood hydrographs at certain locations in a river. The dynamic equations which account for water movement in a tidally affected area are not solved, and there is no accompanying water quality model.

WQON. This model was developed at the Massachusetts Institute of Technology (6). It accounts for the effect of salinity variations on circulation and dispersion in a partially mixed estuary. The salinity model is coupled to the hydrodynamic model. The method used earlier in this chapter to estimate freshwater and saltwater dispersion is used in WQON. This model has not been applied to the lower Hillsborough River.

Model Assessment. The models described are assessed in terms of the basic and additional criteria set forth. This assessment is summarized in Table 3-2. Two of the models do not meet the basic criteria. The USGS Hydrograph Simulation Model is not dynamic and therefore cannot account for tidal forces. The State DER model "RIVER" is neither time variable nor dynamic.

Based on additional criteria, the MIT model "WQON" can account for the effect of salinity variations on circulation and dispersion. It also accepts time variable loadings, and is documented. The USF model has been calibrated and verified in the lower Hillsborough River for both hydrodynamics and water quality, but documentation is not complete.

The need for simulation of salinity variations appears to be important, but must be established by collection of additional data. Until this major question is answered, it is not known which model is more applicable to the NURP study. Whether salinity variations are important or not, the MIT model would require calibration with data from the lower Hillsborough River;

and the USF model would require complete documentation and time variable loadings.

TABLE 3-2. MODEL ASSESSMENT
OF LOWER HILLSBOROUGH RIVER

	Model identification			
Basic criteria	USF	State DER	USGS	MIT
Time variable	X		X	X
Dynamic	X			X
One-dimensional	X	X	X	X

	Model identification	
Additional criteria	USF	MIT
Salinity variation		X
Dispersion		X
Time-variable loads		X
Documentation		X
Hydrodynamic calibration	X	
Water quality calibration	X	

REFERENCES

1. Ross, Bernard E., "A Mathematical Model of the Lower Hillsborough and Palm Rivers", University of South Florida, College of Engineering, May, 1980.

2. Thatcher, M.L., and D.R.F. Harleman, "A Mathematical Model for the Prediction of Unsteady Salinity Intrusion in Estuaries" Report No. 144, Department of Civil Engineering, Massachusetts Institute of Technology, February 1972.

3. Ippen, A.T. and D.R.F. Harleman, "One-Dimensional Analysis of Salinity Intrusion in Estuaries",T.B. No.5, Committee on Tidal Hydraulics, US Army Corps of Engineers, June 1961.

4. Yousef, Yousef A., "Wasteload Allocation for Tampa Bay Tributaries", Florida Technological University, College of Engineering, Technical Report #ESEI-5, July 1976.

5. Turner, James F., Jr., "Hydrograph Simulation Models of the Hillsborough and Alafia Rivers, Florida: A Preliminary Report", USGS Open File Report 72025, Tampa, Florida, 1972.

6. Dailey, James E., and D.R. Harleman, "Numerical Model for the Prediction of Transient Water Quality in Estuary Networks", Report Number 158, Department of Civil Engineering, Massachusetts Institute of Technology, October, 1972.

HILLSBOROUGH RESERVOIR

General

Hillsborough Reservoir, shown in Figure 4-1, is a section of Hillsborough River above the City of Tampa Dam. The Reservoir is a water supply for the City of Tampa and is considered for the purposes of this assessment to extend for approximately 9.5 miles from Fowler Avenue downstream to the City Dam. The drainage area directly tributary to the Reservoir comprises approximately 20 square miles of mostly urban development and open space. The watershed above Fowler Avenue drains approximately 630 square miles, the land use of which is mostly undeveloped and agricultural. Water that drains into the Reservoir normally flows over the City Dam into the lower Hillsborough River. During flood conditions flow may be diverted to the Palm River through the partially completed by-pass canal.

Data Base Summary

The purpose of this section is to identify the type and source of existing data used in the subsequent evaluation of the Hillsborough Reservoir.

Physical data describing the Hillsborough Reservoir and used in this analysis include:

1. Depth and cross-sectional data collected by the University of South Florida.
2. Flow data collected by the USGS and the City of Tampa.
3. Rainfall data collected by the U. S. Weather Bureau.

Information collected by the University of South Florida describes 47 cross-sections from the Tampa Dam upstream past Fowler Avenue for a total of approximately 13 miles. The upstream end of the cross-sectional data is at the confluence of Front Creek as shown in Figure 4-1. The cross sections have been measured at an interval of about 1,500 feet. A profile of the Hillsborough Reservoir based on these data is shown in Figure 4-2. The USGS gages flow at the City of Tampa Dam and Morris Bridge (approximately 19 miles upstream of the Dam). The USGS also records stage heights at Fowler Avenue.

In the Hillsborough Reservoir the water quality data reviewed include:

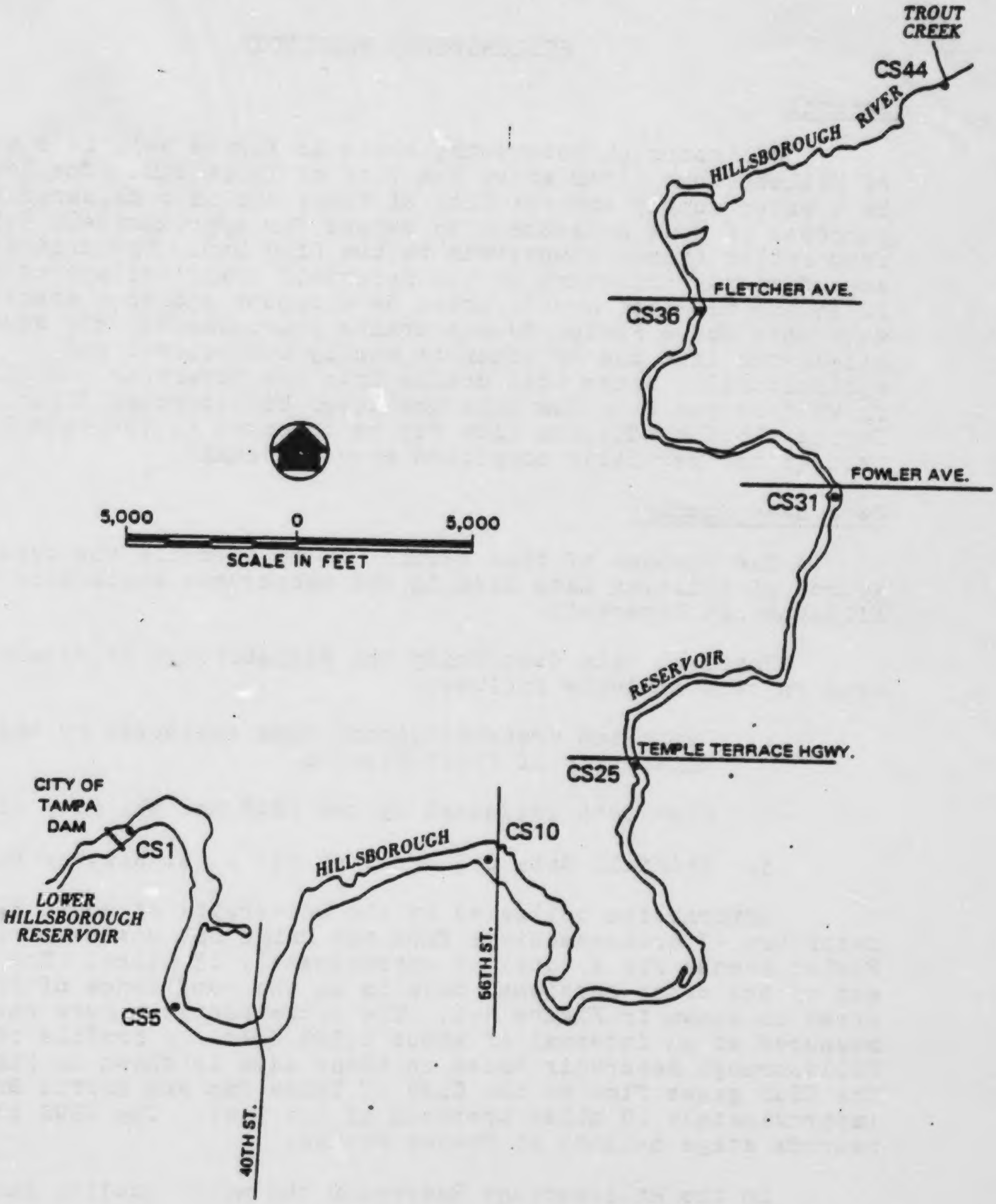
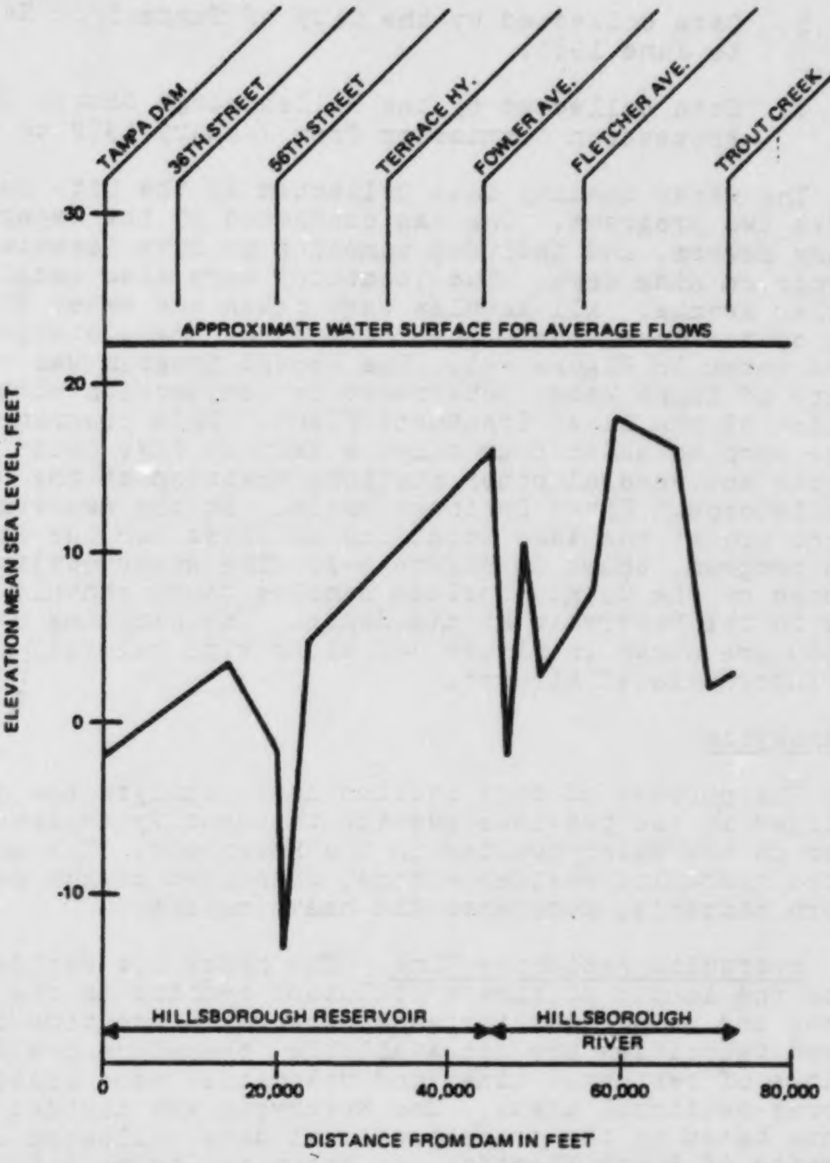

TROUT CREEK
CS44
HILLSBOROUGH RIVER
FLETCHER AVE.
CS36
FOWLER AVE.
CS31
5,000
0
5,000
SCALE IN FEET
RESERVOIR
TEMPLE TERRACE HGWY.
CS25
CITY OF TAMPA DAM
CS1
LOWER HILLSBOROUGH RESERVOIR
HILLSBOROUGH
CS10
56TH ST.
CS5
40TH ST.

FIG. 4-1 PLAN OF HILLSBOROUGH RESERVOIR SHOWING SAMPLING LOCATIONS



SOURCE: UNIVERSITY OF SOUTH
FLORIDA, CENTER FOR
MATHEMATICAL MODELS.

FIG. 4-2 BOTTOM PROFILE OF HILLSBOROUGH RESERVOIR

1. Data collected by the City of Tampa from September 1977 to June 1980.

2. Data collected by the Hillsborough County Environmental Protection Commission from January 1972 to July 1980.

The water quality data collected by the City personnel includes two programs. One was conducted by the Department of Sanitary Sewers, and included sampling at five locations in the Reservoir on nine days. Two locations were also sampled upstream of Fowler Avenue. All samples were taken one meter above the bottom of the Reservoir. The location of these stations (denoted CS) are shown in Figure 4-1. The second program was conducted by the City of Tampa Water Department in conjunction with the operation of the Water Treatment Plant. This program includes surface samples taken four times a year at five locations in the Reservoir and several other stations upstream of the Reservoir in the Hillsborough River Drainage Basin. In the Reservoir, the stations are at the same locations as those for the Sanitary Sewers program, shown in Figure 4-1. The water quality data collected by the County include samples taken monthly at Fowler Avenue in the Reservoir at mid-depth. The sampling dates for 1979 and 1980 are shown in Figure 4-3 along with rainfall measured at Tampa International Airport.

Data Analysis

The purpose of this section is to analyze the data base identified in the previous section to identify impacts of wet weather on the water quality in the Reservoir. The analysis includes hydraulic residence time, dissolved oxygen resources, coliform bacteria, nutrients and heavy metals.

Hydraulic Residence Time. The hydraulic residence time affects the length of time a pollutant remains in the Reservoir. As flows and velocities increase, the residence time decreases. Measured velocities are not available, therefore preliminary estimates of residence times and velocities were based on flows and cross-sectional areas. The Reservoir was divided into two segments based on the cross-sectional data collected by the University of South Florida. As shown in Figure 4-2, the depths generally increase from Fowler Avenue to the Dam. The upper half of the Reservoir is approximately 10 feet deep and 200 feet wide and the lower half is approximately 20 feet deep and 500 feet wide.

The estimated residence times and velocities calculated for a range of flow conditions are summarized in Table 4-1. During dry weather months the residence times are on the order of two weeks. During wet weather months average residence times are several days in length. During more extreme conditions, the residence time is approximately one month for a low flow of 70 cfs and between one and two days for a high flow of 2,000 cfs.

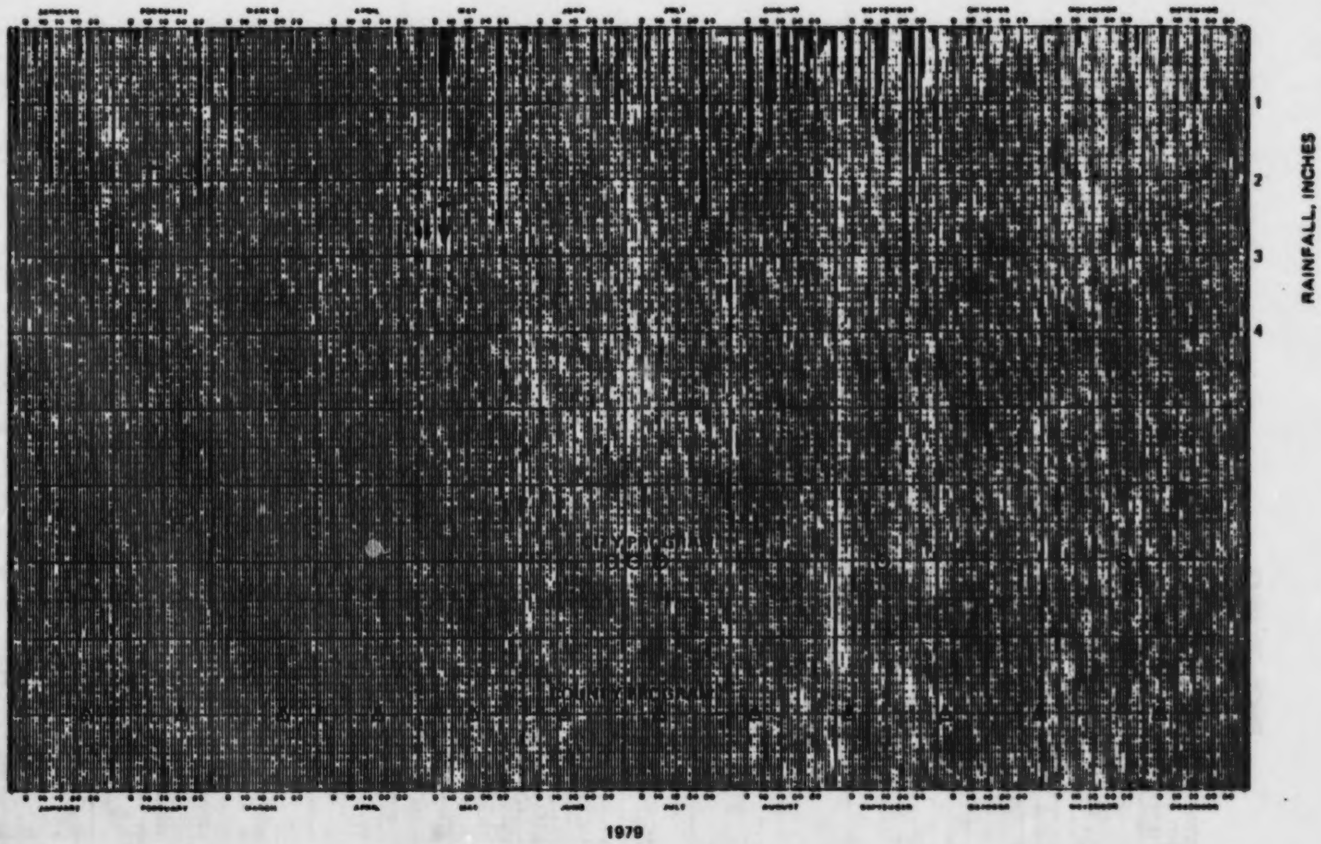


FIG. 4-3 WATER QUALITY SAMPLING DATES – HILLSBOROUGH RESERVOIR, 1979

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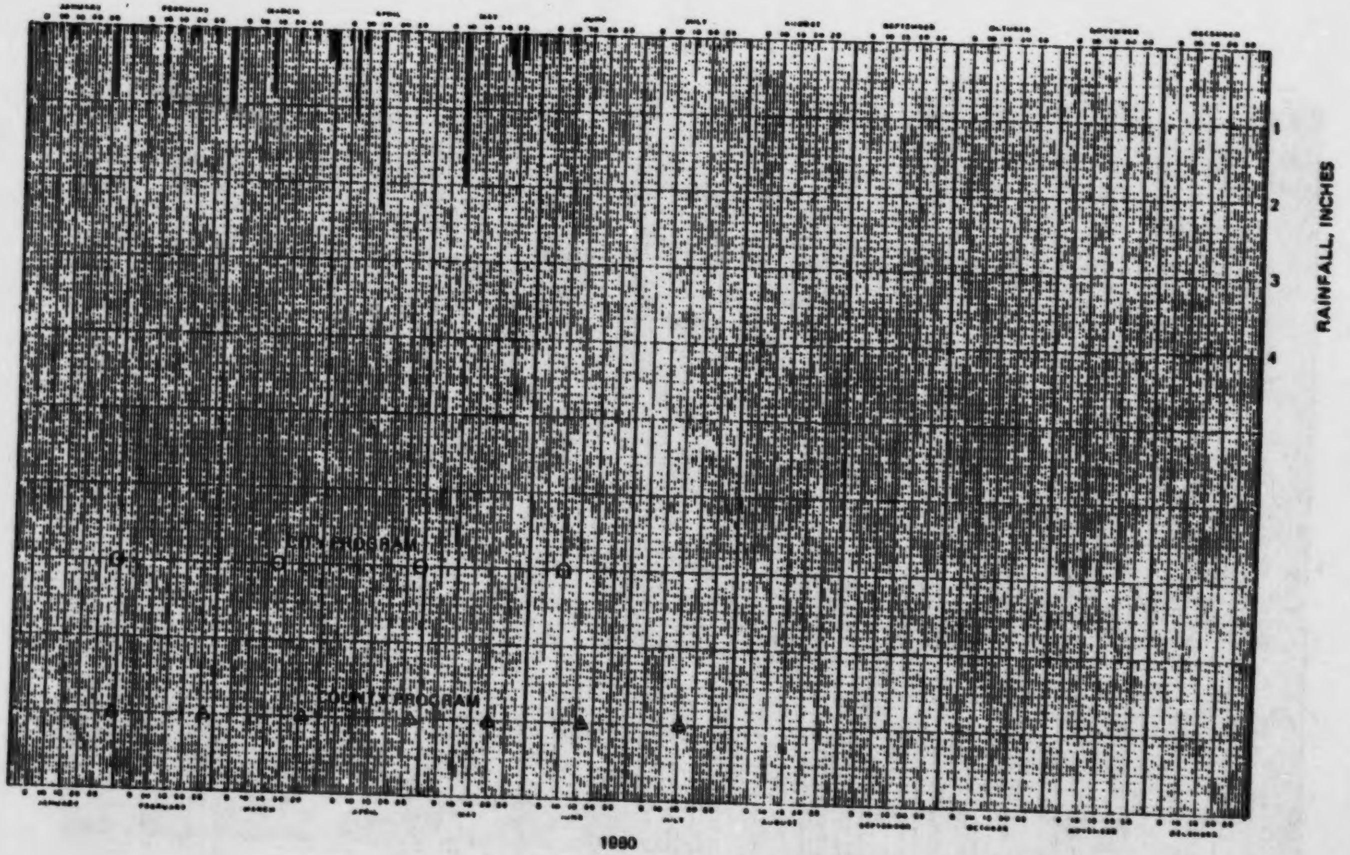


FIG. 4-3 (Continued). WATER QUALITY SAMPLING DATES – HILLSBOROUGH RESERVOIR, 1980

The residence time calculations were done using a 100 percent hydraulic efficiency.

TABLE 4-1. HYDRAULIC RESIDENCE TIMES - HILLSBOROUGH RESERVOIR

Flow, cfs	Average velocities,(1) ft/sec	Hydraulic residence time,(2) days
70(3)	.03 to .01	35
200(4)	.08 to .03	14
850(5)	.30 to .12	3
2000(6)	.65 to .25	1.5

1. Average velocities for upper and lower section in the Reservoir.
2. Hydraulic residence time from Fowler Avenue to Tampa Dam.
3. Low flow approximately equal to water treatment plant withdrawal.
4. Average dry month (Nov.-Jun.).
5. Average wet month (Jul.-Oct.).
6. Peak wet month (Sept.).

Hydraulic efficiency is the ratio of the actual average residence time divided by the theoretical displacement time. By using a 100 percent efficiency the flow is considered to move evenly through the entire cross-section. Actually, the hydraulic efficiency would be something less than 100 percent, especially at lower flows. For example, if 50 percent hydraulic efficiency is used the residence times are reduced by one half. Sufficient data to allow accurate determination of the hydraulic efficiency in the Reservoir is not available. It is expected to be between 50 and 100 percent based on measurements in similar water bodies. During dry weather periods residence times are therefore expected to be on the order of one to four weeks and during wet weather periods about one or two days.

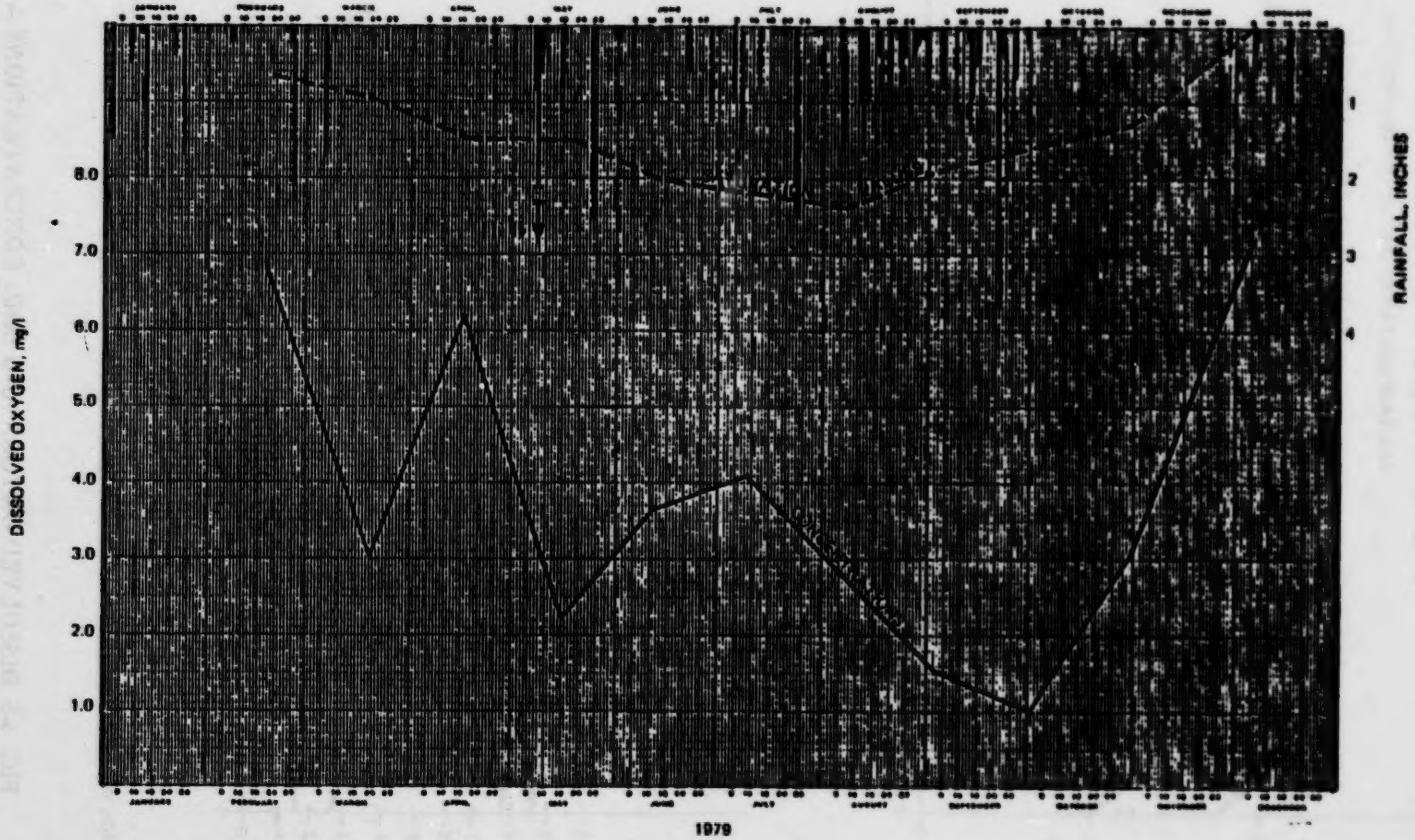
Due to the combination of longer residence times and lower base flows during dry periods, the impact of urban stormwater runoff may be most significant when a rainstorm in the urban area occurs during a dry month. This combination of conditions would tend to create the largest pollution load to the Reservoir from the urban area during periods with the least amount of dilution from upstream flows.

Dissolved Oxygen Resources. Dissolved oxygen data collected by the County at Fowler Avenue during 1979 are presented in Figure 4-4 along with DO saturation concentrations. The measurements were taken at mid-depth. The DO concentrations through most of the year follow roughly the trend of the saturation concentrations, with a deficit of 4 to 5 mg/l. During the high flow period in the summer, however, the DO concentrations decrease to a value of about 1.0 mg/l by the end of September. This reduction in wet weather DO concentrations is not paralleled by an increase in BOD_5 concentrations, which remain between 0.8 and 1.5 mg/l throughout the year. This drop in DO may be related to control of algal activity. The City of Tampa uses algicides during the spring and summer to suppress nuisance blooms. The settling and decay of this dead matter can create an oxygen demand, especially near the Reservoir bottom. This DO demand would not be reflected in high BOD values in the water column. As shown in Figure 4-4 measured concentrations are below the State standard of 4 mg/l during a large portion of the year.

The data collected during the City of Tampa sampling program at a depth one meter above the bottom are used to observe variations in DO concentration through the Reservoir. The bottom measurements of DO in the upstream shallower part of the Reservoir generally range from 3 to 6 mg/l and in the downstream deeper half of the reservoir the range is from 0.5 to 7 mg/l. The lowest values (below 3.0 mg/l) are measured in the spring and summer months in the deeper downstream portion of the Reservoir. The deeper portion of the Reservoir is more difficult to flush out and reaerate and is therefore more susceptible to DO depletions from trapped decaying organic matter.

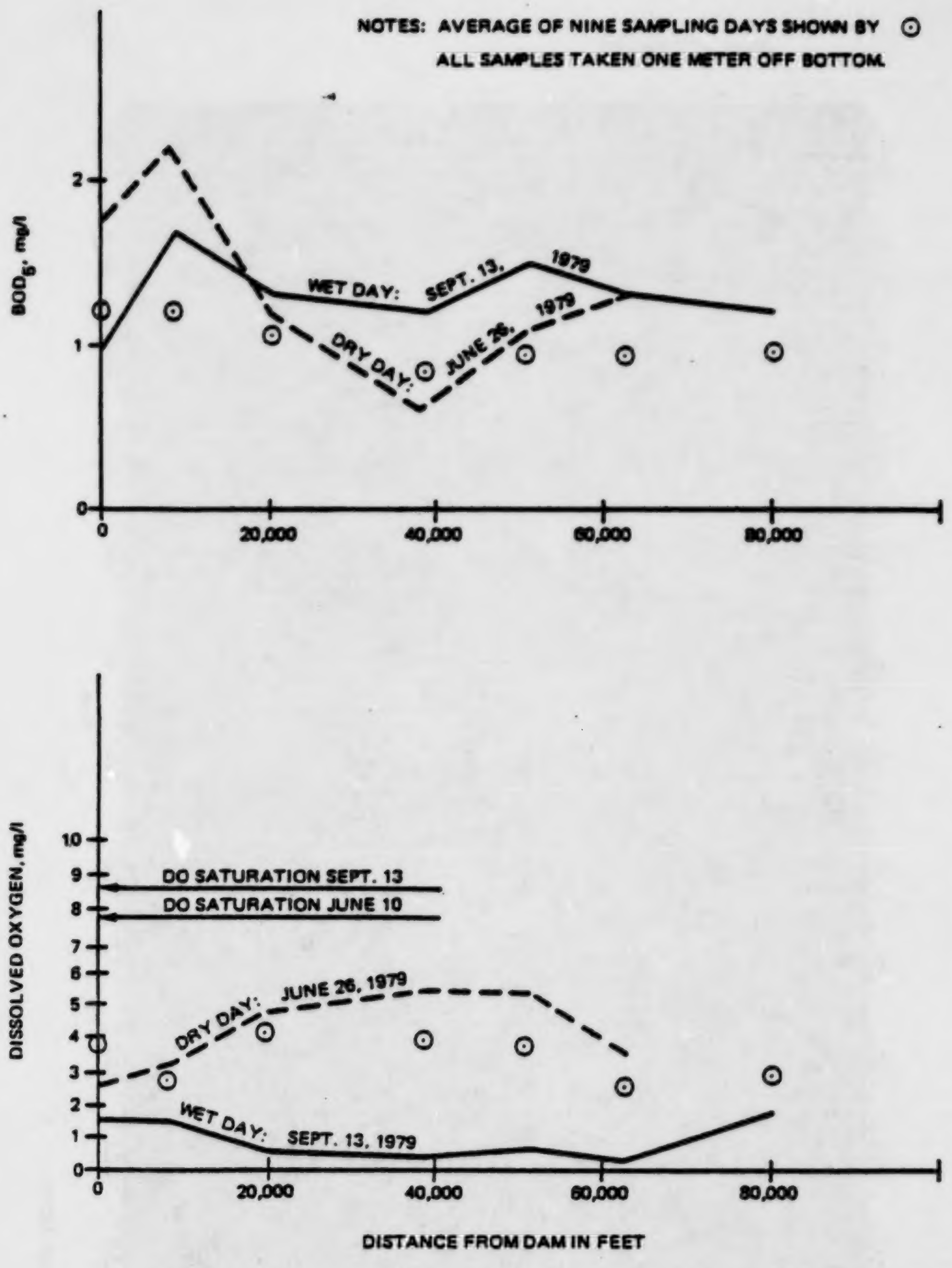
In order to assess the effect of individual storms in the Reservoir, a wet day and a dry day were selected for comparison. It was suggested previously that a storm during the dry period of the year would be expected to have the most impact on the water quality in the Reservoir, but such a condition was not sampled. Of the available sampling periods, only September 13, 1979, during the wet season, was directly preceded by rainfall. Therefore these data are plotted in Figure 4-5 along with data collected on June 26, 1979. The second date is not affected by rainfall and is as near in time as possible to September 13, 1979. Data collected on these two dates are expected to be influenced not only by rainfall but also by seasonal conditions. Figure 4-5 also includes the average DO values for all nine days sampled by the City.

The DO concentrations one meter above the bottom of the Reservoir violate the State standards of 4.0 mg/l during the wet day at all stations. During the dry day DO's are less than 4.0 mg/l in the deeper portions of the lower Reservoir and the deeper sections of the River entering the Reservoir. The DO values on the selected wet day are consistently lower than the average for all samples and also for those values measured on the selected dry day.



SOURCE: HCEPC.

FIG. 4-4 DISSOLVED OXYGEN CONCENTRATIONS AT FOWLER AVENUE – HILLSBOROUGH RESERVOIR, 1979



NOTES: AVERAGE OF NINE SAMPLING DAYS SHOWN BY ⊙
ALL SAMPLES TAKEN ONE METER OFF BOTTOM.

SOURCE: CITY OF TAMPA.

FIG. 4-5 DISSOLVED OXYGEN AND BOD$_5$ CONCENTRATIONS – HILLSBOROUGH RESERVOIR

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There are several factors which could contribute to the extremely low DO values measured on September 13, 1979. One factor may be the seasonal trend toward low DO concentrations during August and September as shown in Figure 4-4. Another factor could be the pollution load entering from the adjacent urban area and the upstream watershed during wet weather. The BOD_5 concentrations are also plotted in Figure 4-5. The concentrations on the wet day are between 1.0 and 1.6 mg/l. The BOD_5 concentrations on the dry day are similar to those on the wet day, indicating that the BOD measured on the wet day either may have been depleted or that other factors influence the DO concentrations.

In order to determine whether the low DO concentrations on September 13 are due to individual storm events or long term seasonal trends, a number of additional measurements are needed. These include conditions before, during and after a storm, the pollution loadings from the River and adjacent urban areas, the amount of algal activity, the characteristics and oxygen demand of the bottom sediments, and the vertical variation of DO values. Available data do not allow a firm conclusion on the effects of wet weather on DO concentrations.

Coliform Bacteria. The 1979 coliform data collected at mid-depth in the Reservoir at Fowler Avenue by HCEPC are plotted in Figure 4-6. Except for one sample, fecal coliform concentrations are below 1,000 MPN/100 ml and are consistently low even during and after the wet months of August and September. The total coliform concentrations are fairly constant at about 1,000 MPN/100 ml except for two values, one during a dry period in February and one during a wet period in September. The reason for the high value in February is not readily apparent, but may be the result of a dry weather discharge. The high concentration measured in September could be due to the higher flows and loads resulting from runoff.

The fecal coliform concentrations measured by City personnel throughout the bottom portions of the Reservoir consistently show low fecal levels (less than 200 MPN/100 ml) which are within the State Standards for drinking water. Total coliform levels are also low, generally less than 2,000 MPN/100 ml with values never exceeding 10,000 MPN/100 ml.

Total coliform counts were somewhat higher in the upstream portion of the Reservoir indicating a possible upstream source. The highest fecal coliform counts were measured in the downstream portion of the Reservoir adjacent to the urban area. These trends are shown in Figure 4-7 for the average coliform concentrations collected on nine days by the City personnel. Also presented in Figure 4-7 are the wet and dry days which were used to describe DO in the previous section. In both cases the wet day has higher total and fecal coliform concentrations. It is important to note, however, that these bottom concentrations are fairly low and do not indicate significant pollution sources.

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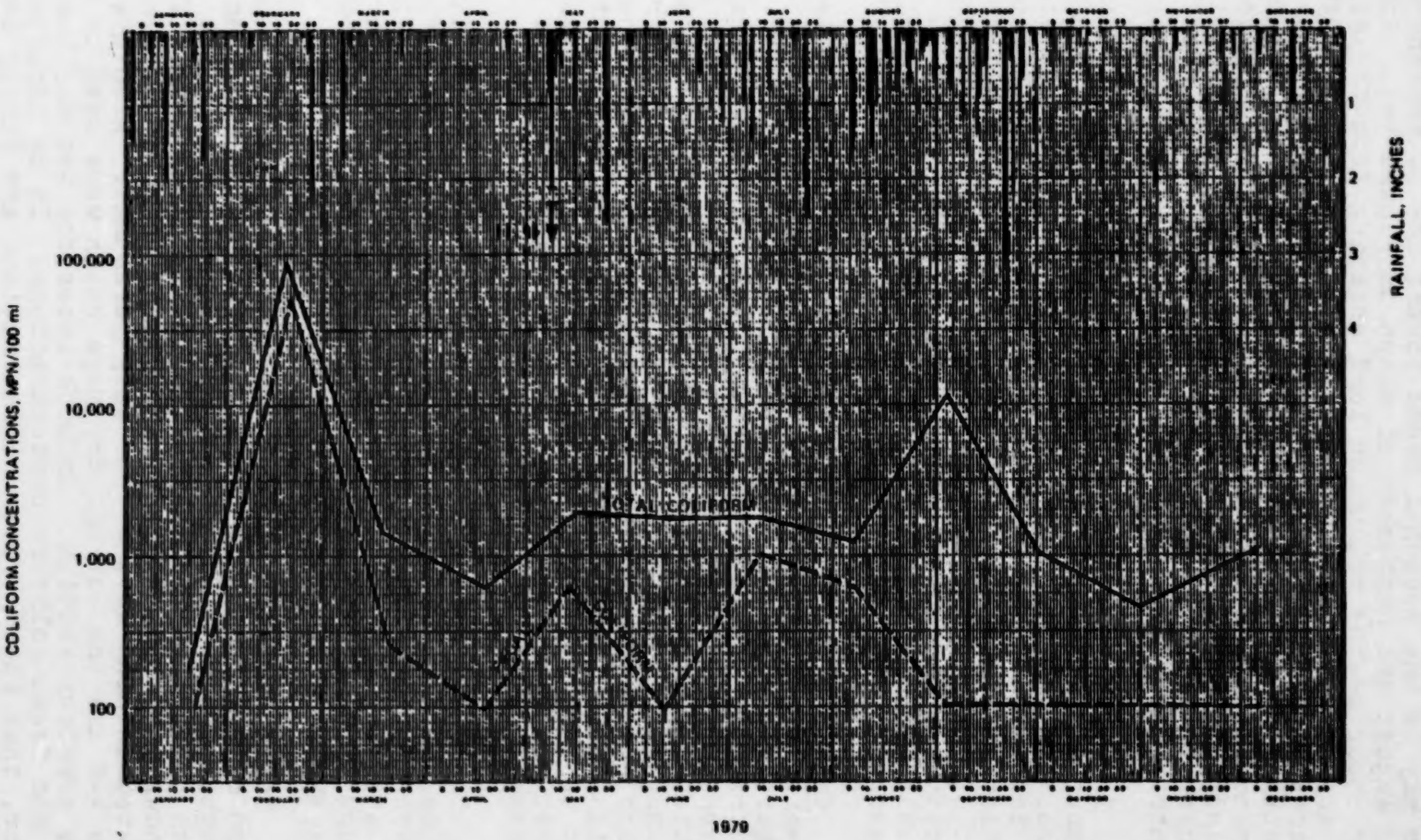
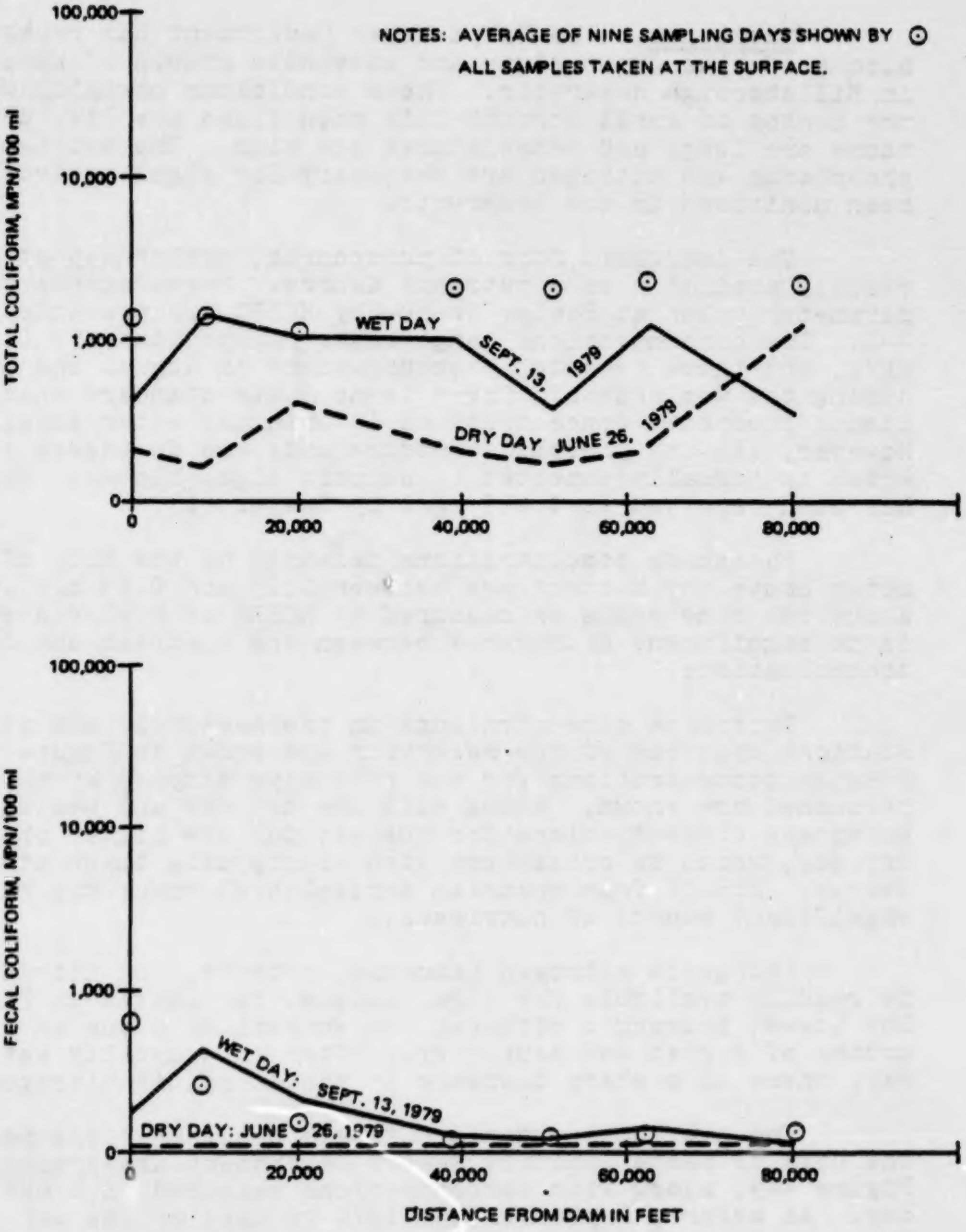


SOURCE: HCEPC.

FIG. 4-6 COLIFORM CONCENTRATIONS AT FOWLER AVENUE – HILLSBOROUGH RESERVOIR, 1979



NOTES: AVERAGE OF NINE SAMPLING DAYS SHOWN BY ⊙

ALL SAMPLES TAKEN AT THE SURFACE.

SOURCE: CITY OF TAMPA.

FIG. 4-7 COLIFORM CONCENTRATIONS – HILLSBOROUGH RESERVOIR

Nutrients. The Tampa Water Department has reported yearly blooms of blue green algae and excessive growth of Water Hyacinth in Hillsborough Reservoir. These conditions normally occur during the months of April through July when flows are low, detention times are long, and temperatures are high. The nutrients phosphorus and nitrogen are necessary for algal activity, and have been monitored in the Reservoir.

The inorganic form of phosphorus, orthophosphate, is readily available as a nutrient source. Measurements of this parameter taken at Fowler Avenue by HCEPC are presented in Figure 4-8. The concentrations range between approximately 0.25 and 0.7 mg/l, and there are high concentrations in August and September during the wet season. There is no State standard which directly limits phosphate concentrations in drinking water supplies. However, all the phosphate measurements are in excess of the level which is normally expected to support algal blooms. This level has been reported as 0.015 mg/l by Sawyer (1).

Phosphate concentrations measured by the City of Tampa (one meter above the bottom) are between 0.25 and 0.85 mg/l. This is about the same range as measured by HCEPC at Fowler Avenue. There is no significant difference between the upstream and downstream concentrations.

Phosphate concentrations in the Reservoir and at two stations upstream of the Reservoir are shown in Figure 4-9. The average concentrations for the nine days sampled by the City personnel are shown, along with the dry day and wet day. The phosphate concentrations for the wet day are higher than for the dry day, which is consistent with County data taken at Fowler Avenue. Runoff from upstream agricultural areas may be a significant source of nutrients.

Inorganic nitrogen (ammonia, nitrite, and nitrate), which is readily available for algal uptake, is plotted in Figure 4-8. The lowest inorganic nitrogen concentrations occur in the rainy months of August and September. After an unusually wet period in May, there is a sharp increase in the inorganic nitrogen value.

The average inorganic nitrogen concentrations measured by the City of Tampa Sanitary Sewers Department are presented in Figure 4-9, along with concentrations measured on a wet and dry day. As before, September 13, 1979 is used as the wet day. However, June 26, 1979 cannot be used as the dry day since all the nitrogen compounds were not measured. Therefore, June 10, 1980 is used as a representative dry day because it is during the same time of year and is preceded by two weeks of dry weather.

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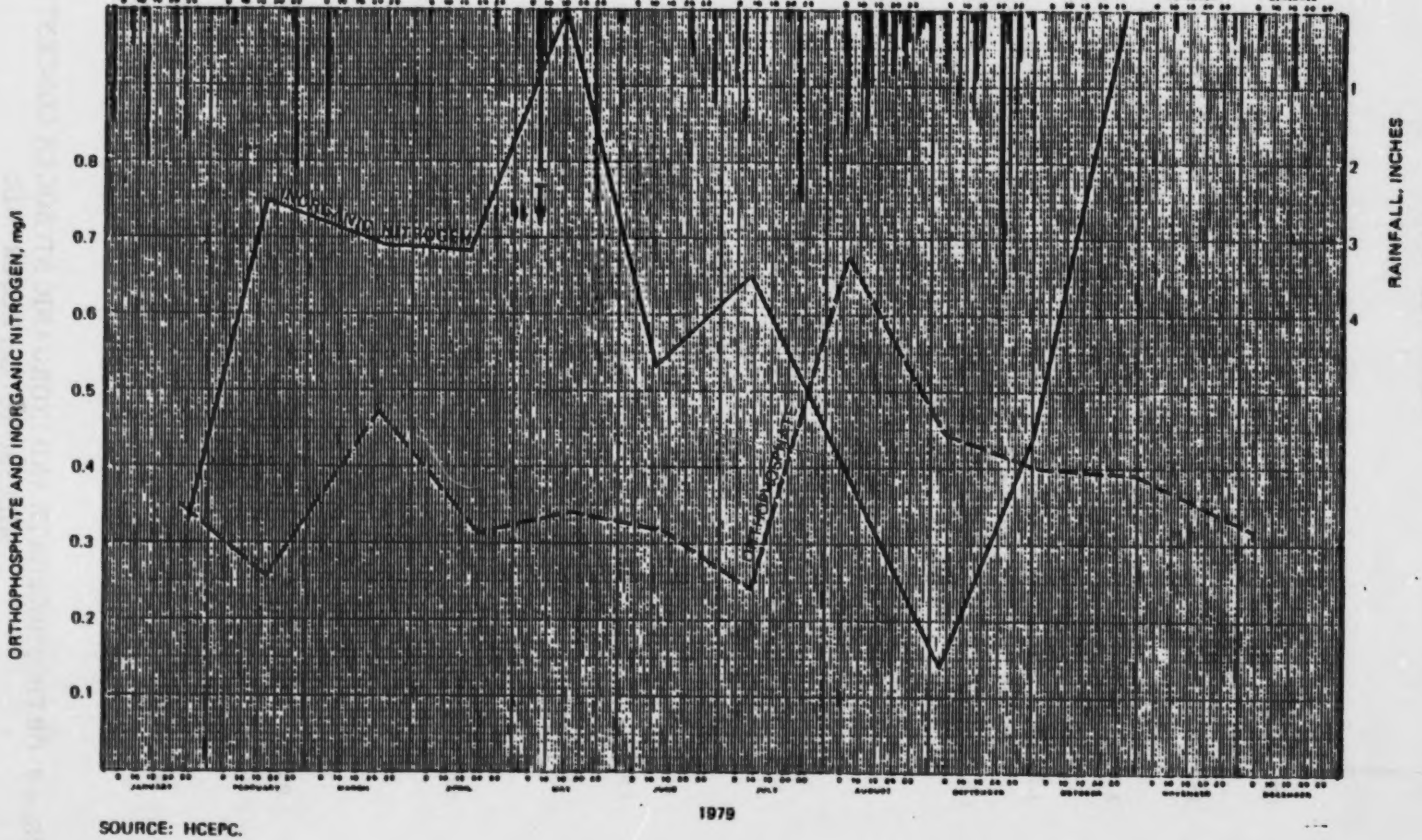
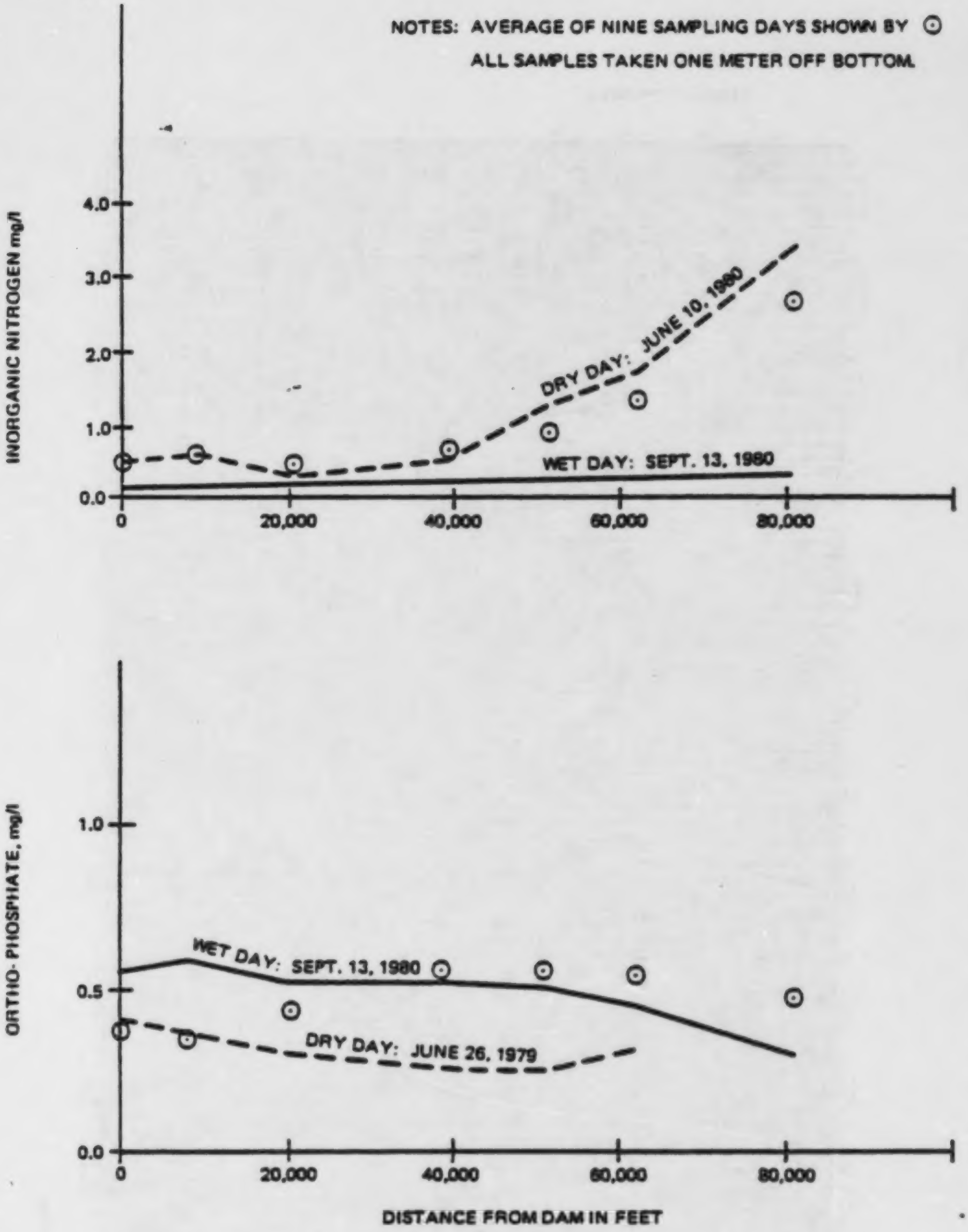


SOURCE: HCEPC.

FIG. 4-8 ORTHOPHOSPHATE AND INORGANIC NITROGEN CONCENTRATIONS AT FOWLER AVENUE – HILLSBOROUGH RESERVOIR, 1979


NOTES: AVERAGE OF NINE SAMPLING DAYS SHOWN BY ⊙
ALL SAMPLES TAKEN ONE METER OFF BOTTOM.

SOURCE: CITY OF TAMPA.

FIG. 4-9 ORTHOPHOSPHATE AND INORGANIC NITROGEN CONCENTRATIONS – HILLSBOROUGH RESERVOIR

In Figure 4-9, the average and dry day inorganic nitrogen concentrations are greater than 2.0 mg/l upstream of the Reservoir and decrease to approximately 0.3 mg/l in the Reservoir. The average inorganic nitrogen concentration entering the Reservoir during these periods is sufficient to support algal blooms. It has been reported by Sawyer (1) that levels of inorganic nitrogen greater than 0.3 mg/l are necessary to support algal blooms. Concentrations on the wet day are less than 0.3 mg/l at all downstream stations. The lower concentrations through the Reservoir during wet weather could be due to flushing from large upstream freshwater flows. During dry weather the inorganic nitrogen values are uniformly above 0.3 mg/l. This is supported by the HCEPC data and the data collected by the Water Department.

Heavy Metals. Heavy metal concentrations collected in the Reservoir by the City of Tampa Water Department are summarized in Table 4-2. The data represent 11 sampling periods over the last three years, of which two were preceeded by rainfall. Copper decreases during wet weather and cadmium does not change. Both dry and wet weather values for copper and cadmium are below the criteria for the protection of freshwater aquatic life. Lead concentrations are about the same during wet and dry weather and are close to the criteria for protection of aquatic life. Mercury concentrations decrease during wet weather but are above the criteria for protection of aquatic life.

TABLE 4-2. CONCENTRATIONS OF HEAVY METALS IN THE HILLSBOROUGH RESERVOIR

	Concentrations, mg/l		
Parameter	Dry weather(1)	Wet weather(2)	Criteria for the protection of freshwater aquatic life(3)
Copper	.005	.003	.08
Lead	.019	.021	.02
Mercury	.00055	.00023	.00005
Cadmium	.002	.002	.004 (soft water) .012 (hard water)

1. City of Tampa Water Department, Quarterly Survey, average of nine days between 1977 and 1980.
2. City of Tampa Water Department, Quarterly Survey, average of two days between 1978 and 1979.
3. U.S. EPA, Quality Criteria for Water, 1976.

It is interesting to look more closely at the wet weather data of the two metals (lead and mercury) that exceed the EPA criteria. Of the two sampling periods preceeded by rainfall, one occurred during the dry season (December 1978) and one occurred during the wet season (September 1979). The concentration measurements of lead and mercury were lower during the wet season. The average concentration of lead was 0.034 mg/l after a storm in the dry season and 0.008 mg/l after a storm in the wet season. For mercury the average concentration during the dry season was 0.0004 mg/l and during the wet season was 0.00005 mg/l. This may indicate that high river flow tends to dilute concentrations during the wet season and that worst case conditions occur during the dry season. A reason for this occurring during the dry season may be large accumulation times between storms which could account for larger pollution loads per storm, and smaller river flows available for flushing. Since wet weather data is limited, only preliminary observations can be made at this time.

Summary. A summary of the apparent effects of wet weather on the Hillsborough Reservoir is presented in Table 4-3. The hydraulic residence time decreases during wet weather due to the higher flow. Dissolved oxygen also decreases, possibly due to algal die-off and decay. DO concentrations violate standards quite often, particularly during the high flow periods of August and September. There appears to be a seasonal decrease of DO during these months, while BOD_5 concentrations do not change significantly. Fecal coliform counts also do not change significantly during the wet periods.

Orthophosphate concentrations may increase during wet weather. High flows seem to dilute inorganic nitrogen, although this may also be a function of algal uptake. Given other favorable conditions, phosphorus concentrations are sufficient for algal growth, but it appears that available nitrogen may limit such growth under certain conditions. Although heavy metal data is limited, it appears that lead is most adversely influenced by wet weather.

The wet weather effects are based primarily on measurements taken one meter above the bottom on individual days. Additional data are needed for a more thorough understanding of the Reservoir. This would include measurements of surface concentrations, vertical variations, and measurements taken before, during and after a storm.

TABLE 4-3. WET WEATHER EFFECTS ON HILLSBOROUGH RESERVOIR

Parameter	Wet weather effect
Hydraulic Residence Time	decreases to several days
Dissolved Oxygen	decreases
Biochemical Oxygen Demand	no apparent change
Fecal Coliform	no apparent change
Orthophosphate	increases
Inorganic Nitrogen	decreases
Heavy Metals	
Copper	decrease
Lead	increase
Mercury	decrease
Cadmium	no apparent change

Model Assessment

In this section, necessary criteria to evaluate stormwater effects on Hillsborough Reservoir are outlined. These criteria are based on the analysis of data in the previous section. Existing models are then described and compared with the identified criteria to assess their potential applicability to the NURP study.

Basic Criteria. In the previous chapters on the lower River and Bay, a time-varying approach which routes flows and pollutants through the system was necessary to model stormwater discharges. This is also a basic criteria for the Reservoir model. Since there is no tidal variation in the Reservoir, dynamic forces are not as significant as in the Bay and the lower River. Therefore, this is not a basic criteria for the Reservoir model.

In addition to being time varying another necessary basic criteria to model the Reservoir is the ability to simulate water quality parameters which are conservative and those which decay with time. Due to the algal bloom problems in the Reservoir the ability to predict nutrients concentrations, especially nitrogen, in the Reservoir is part of the basic water quality criteria.

Existing data in the Reservoir were taken at only one depth. Since no vertical profile information is available, it is not certain at this time whether the Reservoir may become stratified. Therefore, final model selection must be based upon field measurements. It is possible that the Reservoir, because of its relatively shallow depth, would not be stratified. Further, the flow increase during a storm would tend to break down any stratification. A one-dimensional model may therefore be adequate for the Reservoir. This, however, is subject to change following assessment of additional field data.

The three basic criteria for a model in the Reservoir are the ability to be time varying and one dimensional and the ability to simulate conservative and decaying pollutants.

Additional Criteria. Several additional criteria are necessary to model the Reservoir. Criteria described in previous chapters which apply to the Hillsborough Reservoir include time variable loadings, reasonable cost, documentation, and calibration. Additional criteria which apply to the Reservoir include accounting for a control structure at the downstream boundary (the Tampa Dam), and specification of withdrawals of flow at the Water Treatment Plant and Bypass Canal. The downstream control structure boundary condition could be a stage vs. flow relationship.

Existing Model Review. Two of the models used in the lower Hillsborough River and reviewed in Chapter 3 have also been used in the Reservoir. These include RIVER used by the Florida Department of Environmental Regulation (2) and the Hydrograph Simulation Model used by the USGS (3). Two additional models which have not been used in the Reservoir but may be applicable are the USF lower Hillsborough River Model (4), and the MIT model (5). These models were each described in Chapter 3.

Model Assessment. A preliminary assessment of the models which may be applicable to the Reservoir is presented in Table 4-4. This assessment is based on a limited amount of wet weather data and no vertical profile data. The State DER model is not time varying, and the USGS model is a flood routing model with no water quality portion, therefore these models do not meet the basic criteria. The USF model would be applicable if control structures and time variable loads could be simulated. The MIT model would be applicable to the needs of the NURP study, but calibration would be needed. The MIT model has the capability of including a seven step nitrogen cycle.

After sufficient field data becomes available to provide a more detailed understanding of the Reservoir during wet weather conditions, this evaluation will be updated.

Respectfully submitted,

METCALF & EDDY, INC.

Abu M. Z. Alam

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Approved:

Jekabs P. Vittands
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TABLE 4-4. MODEL ASSESSMENT OF HILLSBOROUGH RESERVOIR

	Model identification			
Basic criteria	State DER	USGS	USF	MIT
Time variable		X	X	X
Water quality	X		X	X
One-dimensional	X	X	X	X

	Model identification	
Additional criteria	USF	MIT
Control structure		X
Withdrawals	X	X
Time-variable loads		X
Documentation		X
Calibration		

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BIOLOGICAL AND CHEMICAL STUDIES ON THE IMPACT OF STORMWATER RUNOFF UPON THE BIOLOGICAL COMMUNITY OF THE HILLSBORUUGH RIVER, TAMPA, FLORIDA

FINAL RESEARCH REPORT

SUBMITTED TO:

STORMWATER MANAGEMENT DIVISION
DEPARTMENT OF PUBLIC WORKS
CITY HALL PLAZA, 5N
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MARCH 16, 1984

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BIOLOGICAL AND CHEMICAL STUDIES ON THE IMPACT OF STORMWATER RUNOFF UPON THE BIOLOGICAL COMMUNITY OF THE HILLSBOROUGH RIVER, TAMPA, FLORIDA

Final Research Report

Submitted to:

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March 16, 1984

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APPENDIX

This project was funded, in part, by the City of Tampa, Stormwater Management Division. The following investigators contributed to the biological and chemical studies.

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EXECUTIVE SUMMARY

The present research was initiated as part of the City of Tampa Nationwide Urban Runoff Program (NURP) studies and was intended to assess the impact of urban runoff upon endemic biological communities. Principal activities included laboratory bioassay experiments using both plants and animals exposed to stormwater runoff and sediments and limited field studies on the receiving water body. Biological field studies included benthic infaunal samples taken at four sites during wet and dry seasons; phytoplankton and zooplankton samples collected at four sites during wet and dry seasons; tidal stage sampling of the plankton community at one station; Hester-Dendy multiple plate epifaunal samples; and a survey of shoreline vegetation along the lower river. Laboratory bioassay experiments included algal assays employing both natural and cultured species and animal bioassays using fish and invertebrate species. All bioassays were conducted using urban runoff collected from selected drainage basins prior to entering the Hillsborough River. Chemical characterization of stormwater runoff, river sediments and suspended particulate matter was carried out with emphasis placed upon identification of potentially toxic organic and inorganic forms. Petroleum hydrocarbon analyses were carried out on stormwater, sediments and suspended particulates in order to trace the origin and movement of stormwater associated pollutants. To the best of our knowledge, this study represents a unique approach to the biological and chemical characterization of the relationship between stormwater runoff and pollution problems in an urban receiving water body.

Benthic Studies

The mean densities of all benthic infaunal invertebrates collected in the quantitative samples indicated that during the dry season, all stations except the one furthest upriver were dominated by estuarine species. Moving upstream, freshwater organisms, especially insect larvae, appeared in increasing abundance. During the wet season, the total number of species and density of individuals generally decreased at each station with the most upriver station least affected by the dry to wet season transition. The largest number of species collected at any station was at the river mouth during the dry season. The stations closest to the river mouth contained several pollution indicator species suggesting organically enriched and/or polluted sediments.

Hester-Dendy multiple plate samplers revealed a similar trend as did benthic samples. A higher proportion of aquatic insects and crustaceans were collected on the plates than were present in benthic infaunal samples.

The overall results present a rather typical picture of what would be expected in a system which seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. When under estuarine conditions, more individuals of more species are present than when under freshwater conditions. The system must constantly be readjusting as salinities change. In general, benthic estuarine species are present further upriver than would be expected based upon water column salinities alone.

Animal Bioassays

Laboratory bioassay experiments were conducted using three primary and two secondary standard test species. All bioassay animals were raised in the laboratory under controlled conditions and were ecologically representative of endemic species in the Hillsborough River. The three primary species included a polychaete worm, Neanthes arenaceodentata, a mysid, Mysidopsis bahia, and a fish Cyprinodon variegatus. The secondary species were tested with wet season runoff only and included the stone crab, Menippe mercenaria and a copepod, Pseudocyclops sp.

Laboratory toxicity tests included three separate wet season runoff samples from two different drainage basins, one dry season runoff sample, one series of sediment bioassays involving composite sediment collected from three sites in the river, and a series of suspended particulate phase bioassays prepared from the above sediment samples. A total of 78 separate animal bioassays were completed during the course of this project.

Wet season stormwater runoff was found to be generally non-toxic to test species in both short term and long term experiments. The only significant toxicity for wet season runoff occurred with Mysidopsis after 7 days exposure to 100% stormwater at low salinity.

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Dry season stormwater runoff was significantly toxic for two out of four species tested in short term experiments at low salinities. One of two species tested in long term bioassays displayed significant adverse effects at low salinities. In general, stormwater runoff was less toxic than expected based upon chemical composition alone.

Bioassays with sediments from the Hillsborough River produced significant adverse effects in two of three species tested. Suspended particulate phase tests revealed significant toxicity in one of three species tested. As with stormwater, sediments and suspended particulate matter were less toxic than expected based upon chemical composition alone.

General conclusions which can be drawn from these experiments include: 1) wet season runoff contains relatively low levels of toxic chemicals and does not appear to be toxic to estuarine animals; 2) dry season runoff contains significantly higher concentrations of heavy metals and hydrocarbons and can be acutely toxic to estuarine animals; 3) stormwater displays greater toxicity under low salinity conditions; 4) Hillsborough River sediments contain high concentrations of heavy metals and hydrocarbons and can be acutely toxic to estuarine animals.

Algal Assays

Laboratory bioassays were conducted to determine the effect of stormwater runoff upon field collected and cultured phytoplankton. The stormwater runoff samples tested were from the same collection as the wet season sample used in animal bioassays. In all cases, addition of wet season stormwater stimulated phytoplankton growth relative to control treatments. This suggests that wet season stormwater runoff may serve as a source of nutrients and stimulate phytoplankton growth in the Hillsborough River. Dry season stormwater was not tested in algal assays due to unavailability of runoff samples.

Plankton Studies

Zooplankton and phytoplankton samples were collected at three week intervals from May 7 through August 16, 1982, spanning the dry season to wet season transition for that year. Four stations on the Hillsborough River were sampled on each collection trip. The furthest downstream station was sampled intensively during a low tide to high tide transition.

Zooplankton and phytoplankton densities were higher at all stations during the dry season than during the wet season. Marine organisms were predominant at all but the most upstream station during the dry season and decreased in relative abundance during the wet season. The most downstream station maintained a dominance of marine zooplankton and phytoplankton even during the wet season, indicating that Hillsborough Bay has a strong effect upon the plankton community throughout the year. The Hillsborough River plankton community appears to be controlled largely by physical factors such as tidal forces and river flow rates.

Lower Hillsborough River Shoreline Inventory

The Hillsborough River, from the dam to the bay, has been moderately to severely altered by urbanization. Calculations reveal that 54% of the shorelines have been hardened. Of the hardened portions, about 47% are composed of bulkhead, while about 8% are riprap. Approximately 13% of the river's shores are filled but unhardened, and 34% are more or less native (a total of 102% for these figures is due to their nonexclusive nature). Native vegetation along the river shows a general transition from salt-tolerant species downriver to salt-intolerant forms upriver, although this pattern has been modified due to historical and natural causes.

Four main recommendations can be made based upon the information collected during this survey. These include:

1) The City of Tampa should concentrate on the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements;

2) A three phase plan for shoreline improvements should be developed for the target segment including: (a) creation or restoration of vegetated shorelines on public lands; (b) removal of exotic plant species from natural and filled shorelines; and (c) enhancement of riprap shorelines with native vegetation;

3) The City of Tampa should involve citizens and shoreline owners in waterfront improvement through development of homeowner's guides and incentive programs; and

4) The City of Tampa should seek a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review or code enforcement programs.

Hydrocarbon Studies

Sediment samples for petroleum hydrocarbon analysis were collected at 12 stations spanning the distance from Hillsborough Bay up the river and into the Hillsborough Reservoir. Seven of these stations were also sampled for suspended particulate matter in the water column. Analyses revealed that all sediments sampled contained high levels of hydrocarbons. Petrogenic hydrocarbons increased in relative concentration with increasing distance downriver from the dam and were highest in the vicinity of the downtown I275 bridge. The petrogenic hydrocarbons identified in river sediments were very similar to those identified in stormwater runoff samples from the Artic Street basin and strongly resembled weathered crankcase oil. Stormwater runoff appears to be the principal source of petroleum hydrocarbons found in river sediments.

Wet season and dry season stormwater runoff samples were analyzed for petroleum hydrocarbons and revealed that dry season composite samples were similar to wet season composite samples in concentrations but that dry season "first flush" stormwater was extremely high in petroleum hydrocarbons.

Analysis of suspended particulate matter from the bay, river and reservoir indicated that little hydrocarbon is redistributed due to tidal forces in the lower river during periods of low river flow.

Petroleum hydrocarbons provide a good tracer material for stormwater associated particulate matter, and these results suggest that sediment and pollutant accumulation in the river is directly related to stormwater runoff.

General Conclusions and Recommendations

Stormwater runoff entering the lower Hillsborough River does not pose an acute toxicological problem to most endemic biota. Rapid dilution rates of stormwater and chemical complexion of pollutants into insoluble forms in the river water reduce the direct toxicity of runoff. Based upon chemical composition alone, the acute toxic potential of stormwater runoff would be over estimated, since much of the potentially toxic material is bound in non-bioavailable form. Most state and federal water quality standards are based upon chemical composition of receiving waters and thus urban stormwater runoff may contribute significantly to water quality violations.

The most significant contribution that stormwater runoff makes to chemical and biological pollution problems in the river comes from more or less continuous input of particulate matter containing high levels of potentially toxic chemicals such as heavy metals and petroleum hydrocarbons. This particulate matter accumulates in river sediments and may act as a sink contributing to long term water quality problems. Once deposited in sediments, factors such as lowered salinity, lowered dissolved oxygen, low pH, microbial activity and bioturbation may cause release of toxic chemicals into river water. This deposited particulate matter is also likely responsible for lowered dissolved oxygen levels periodically observed in bottom water.

The City of Tampa should explore appropriate methods for limiting the input to the river of particulate matter from stormwater runoff as a long term goal for improving water quality. Removal of contaminated sediments from the river may provide short term improvements in water quality. Specific recommendations include: 1) removal of existing contaminated sediments from the river; and 2) implementation of the stormwater management plan (Metcalf and Eddy, 1983a) and the recommended improvements in the Hillsborough River shoreline to provide a long-term system for limiting pollutant input into the river.

Future research in the Hillsborough River should concentrate on physical and chemical dynamics of sediment input and accumulation. The depth and chemical composition of existing sediments along the river need to be determined before any mitigative action is taken.

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I. INTRODUCTION

Urban stormwater runoff has been identified as a significant source of pollution in numerous receiving water bodies throughout the country (Burke, 1971; Vitale and Sprey, 1974; Laws, 1981). The sources and concentrations of pollutants carried by urban stormwater runoff (hereinafter referred to as urban runoff) vary tremendously with the characteristics of the drainage basin. In most cases, however, urban runoff can be expected to contain measurable quantities of suspended particulate material, nutrients, bacteria, heavy metals, pesticides and hydrocarbons (Christensen et al., 1978; MacKenzie and Hunter, 1979; Laws, 1981; Miller and Mattraw, 1982; Browne et al., 1982; EPA, 1982). These constituents can have a severe effect upon water quality in receiving waters (Metcalf and Eddy, 1983) and may affect biological communities through direct toxicity of heavy metals, pesticides and hydrocarbons or indirectly through reduced light penetration, reduced dissolved oxygen and excessive phytoplankton growth.

Numerous studies throughout the U.S. have documented the changes in water quality associated with urban runoff but relatively few studies have considered the effects of these water quality changes upon the biological communities in receiving water bodies. The biological studies that have been undertaken were mostly ecological surveys and have attempted to relate community parameters such as species diversity and species richness to the effects of urbanization and urban runoff. Pratt and Coler (1979) studied changes in benthic macroinvertebrate communities along portions of the Green River, Massachusetts representing relatively nonurbanized and urbanized sections. They documented changes in benthic communities which they attributed to increasing urban runoff. Pitt and Bozeman (1980) analyzed water quality, sediment quality and biological communities along urbanized and nonurbanized sections of Coyote Creek, California. Their results indicate that pollution loads increase with increasing urbanization and that the number of species and community composition change with increasing urbanization. These authors also demonstrated that tissue loads of lead and zinc increased in certain organisms along with sediment concentration in urbanized portions of the river. Tomlinson et al. (1980)

studied the effects of storm drains and combined sewer outfalls on marine and freshwater systems and reported significant disruption of biological communities near outfalls relative to unaffected areas.

A number of research projects have approached the biological effects of runoff through bioassays using natural or cultured phytoplankton (algal assays). Yousef et al. (1980) analyzed runoff from Orlando, Florida flowing into Lake Eola and determined its effect upon natural and cultured phytoplankton in laboratory experiments. Their results indicated, among other things, that high stormwater concentrations inhibited algal productivity while diluted runoff significantly increased productivity.

The present biological studies were initiated as part of the City of Tampa Nationwide Urban Runoff Program (NURP) and were intended to assess the impact of urban runoff on endemic biological communities through laboratory bioassay experiments combined with limited field studies. Biological field studies included benthic infaunal samples taken at four sites during wet and dry seasons; phytoplankton and zooplankton samples collected at four sites during wet and dry seasons; tidal stage sampling of the plankton community at one station; Hester-Dendy multiple plate epifaunal samples; and a survey of shoreline vegetation along the lower river. Laboratory bioassay experiments included algal assays employing both natural and cultured species and animal bioassays using fish and invertebrate species. All bioassays were conducted using urban runoff collected from selected drainage basins prior to entering the Hillsborough River.

The biological studies were supplemented with organic and inorganic chemical analyses of runoff, sediments and suspended particulate matter. A detailed analysis of petroleum hydrocarbons in these fractions was undertaken in order to determine the origin of sediment associated pollutants in the river.

The present research has added a significant component to our understanding of the biota within the Hillsborough River and how it may be affected by short term and long term input of stormwater runoff and associated pollutants. Some of the remaining problems that need attention include analysis of the synergistic effects of combined pollutants, as are found in runoff and sediments, upon receiving water organisms; the effects of pulse-loading of pollutants upon endemic organisms; the bioavailability of sediment associated pollutants; the sediment input and export budget of the river; the mobility of pollutants in sediments under varying physical and chemical conditions; and the food chain dynamics associated with urban runoff pollutants.

Artic Street Drainage Basin

The Artic Street watershed covers an area of 0.34 mi^2 and is located in Sulphur Springs, 5.5 miles north from downtown Tampa (Figures 1 & 3). The watershed is elongated, about 1.4 miles in length and 0.5 mile wide, draining southward through an underground stormsewer system with grated street inlets. The drain is tributary to the Hillsborough River. Land development is about evenly divided between older single unit residences and commercial businesses with several large shopping centers making up most of the commercial development. Florida Avenue, a heavily traveled four-lane street, runs the length of the watershed and is highly developed commercially, including fast-food restaurants and car dealerships. USGS streamflow, rainfall and water quality data are collected at a station installed in a 72 inch diameter stormsewer under Yukon Street.

Cass Street Drainage Basin

The Cass Street watershed covers an area of 0.02 mi^2 and is located within downtown Tampa (Figures 2 & 3). The drainage basin is elongated and drains westward through an underground stormsewer system with grated street inlets. Land use is commercial, with a large percentage of paved streets contributing to its 100% impervious area. USGS measurements are taken at the stormsewer outlet under the Cass Street-Hillsborough River Bridge.

Stormwater Runoff Collection

Four discrete samples of stormwater runoff were collected by City of Tampa personnel for use in bioassay experiments and chemical analyses. Three of these stormwater samples were collected from the Artic Street watershed and were obtained on July 16 and October 14, 1982, and May 4, 1983. The July 16 storm event produced a total of 0.44 inches of rainfall (averaged between two rain gauges) and lasted for one hour, 18 minutes. Similar rainfall events had occurred on July 14 and 15 with a larger event recorded on July 13 at one of the rainfall collection sites (0.75 inches at the northern boundary of the watershed). The October 14 storm dropped 0.55 inches of rain and lasted for two hours, 14 minutes. Previous rain events included a 1.70 inch storm on October 1 and three storms (0.05; 0.08; and 0.12 inches) between October 2 and 14. The stormwater samples collected from the July 16 and October 14, 1982 events were composed of time-composite subsamples obtained at two minute intervals throughout the event and then pooled.

The May 4, 1983 storm event resulted in 0.12 inches of rainfall (measured at the northern boundary of the watershed) and lasted for one hour. This sample was collected as a flow-composite with subsamples obtained every three minutes throughout the event. Each subsample was pooled in proportion to flow rate measured at the time of sample collection. One gallon of "first flush" stormwater runoff was collected and retained for chemical analysis.

One stormwater sample, collected on January 21, 1983, came from the Cass Street watershed. This event produced 0.50 inches of rain and lasted for one hour, 50 minutes. A storm recorded for the previous day produced 0.95 inches of rain. The Cass Street stormwater represented a time-composite sample.

All stormwater samples were mixed thoroughly in the field and placed into 5 gallon polyethylene containers for transport. These containers were stored in the laboratory at 4°C. Based upon the chemical analyses and relative toxicities of the various stormwater samples, the Artic Street stormwater collected on July 16 and October 14 and the Cass Street stormwater, are considered to represent "wet season runoff". The Artic Street sample collected on May 4, 1983 is considered to represent "dry season runoff".

Sediment Samples Used in Bioassays

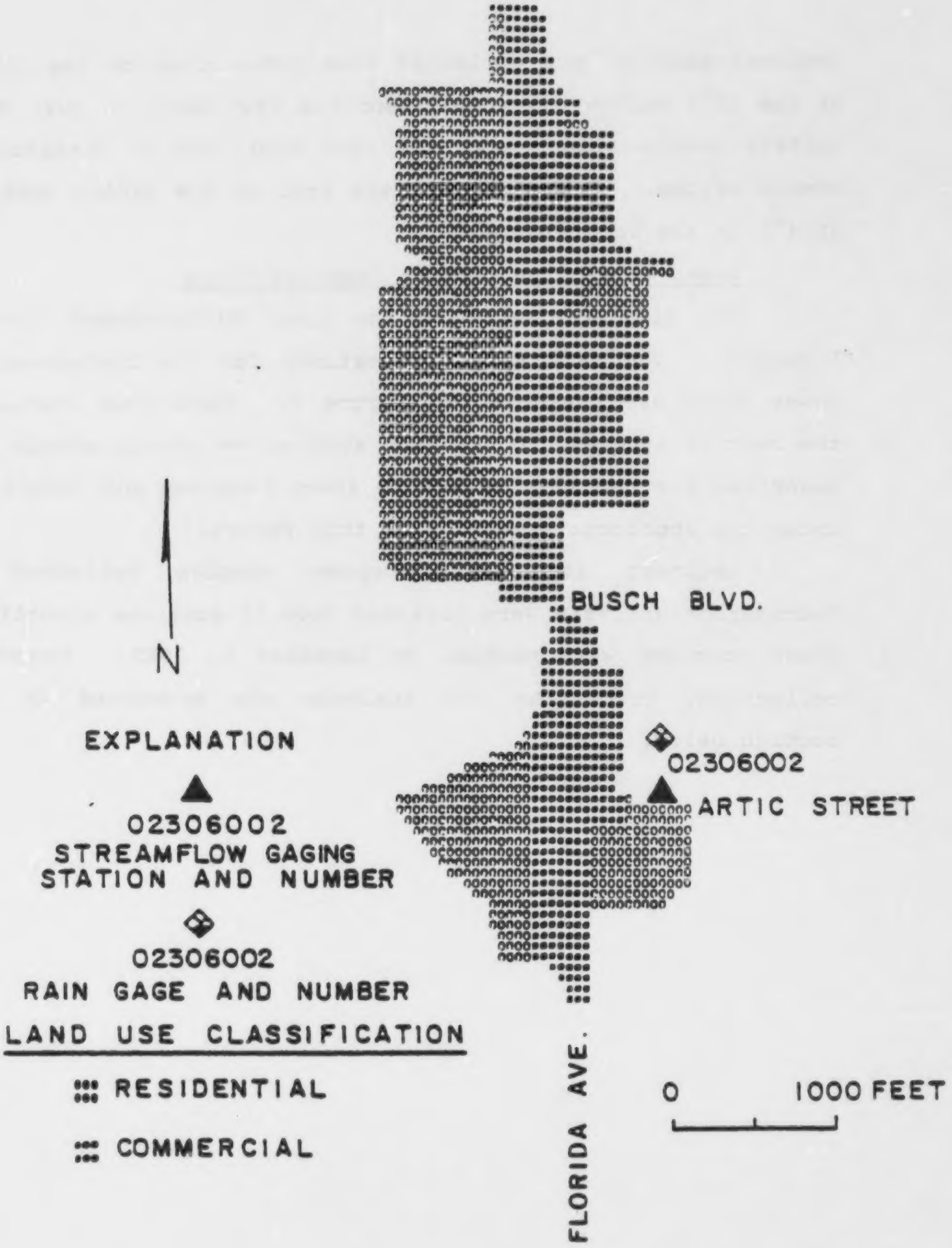
Sediment samples for use in whole sediment and suspended particulate phase bioassays were collected from the Hillsborough River on May 16, 1983. These samples were collected with a petite Ponar sampler and placed into acid washed polyethylene containers on ice. Care was taken to avoid any sediment that had come into direct contact with the sampling device.

Sediment samples were collected from three sites on the river: 1) upstream of the I275 Bridge (downtown) near the west bank; 2) just downstream of the Buffalo Avenue bridge near the west bank; and 3) downstream of the Sligh Avenue bridge. These samples were kept on ice during transport and stored at 4°C in the laboratory.

Lower Hillsborough River Sampling Sites

The City of Tampa and the lower Hillsborough River are shown in Figure 3. The main sampling stations for the biological studies on the lower river are presented in Figure 4. These four stations were used in the benthic studies, zooplankton studies and phytoplankton studies, and are described further with regard to exact location and sampling methodologies under the appropriate section of this report.

Sediment and water column samples collected for petroleum hydrocarbon analysis were obtained from 12 stations identified in Figure 5. These stations were sampled on December 1, 1983. Procedures for sample collection, processing and analysis are presented in the appropriate section below.


BUSCH BLVD.
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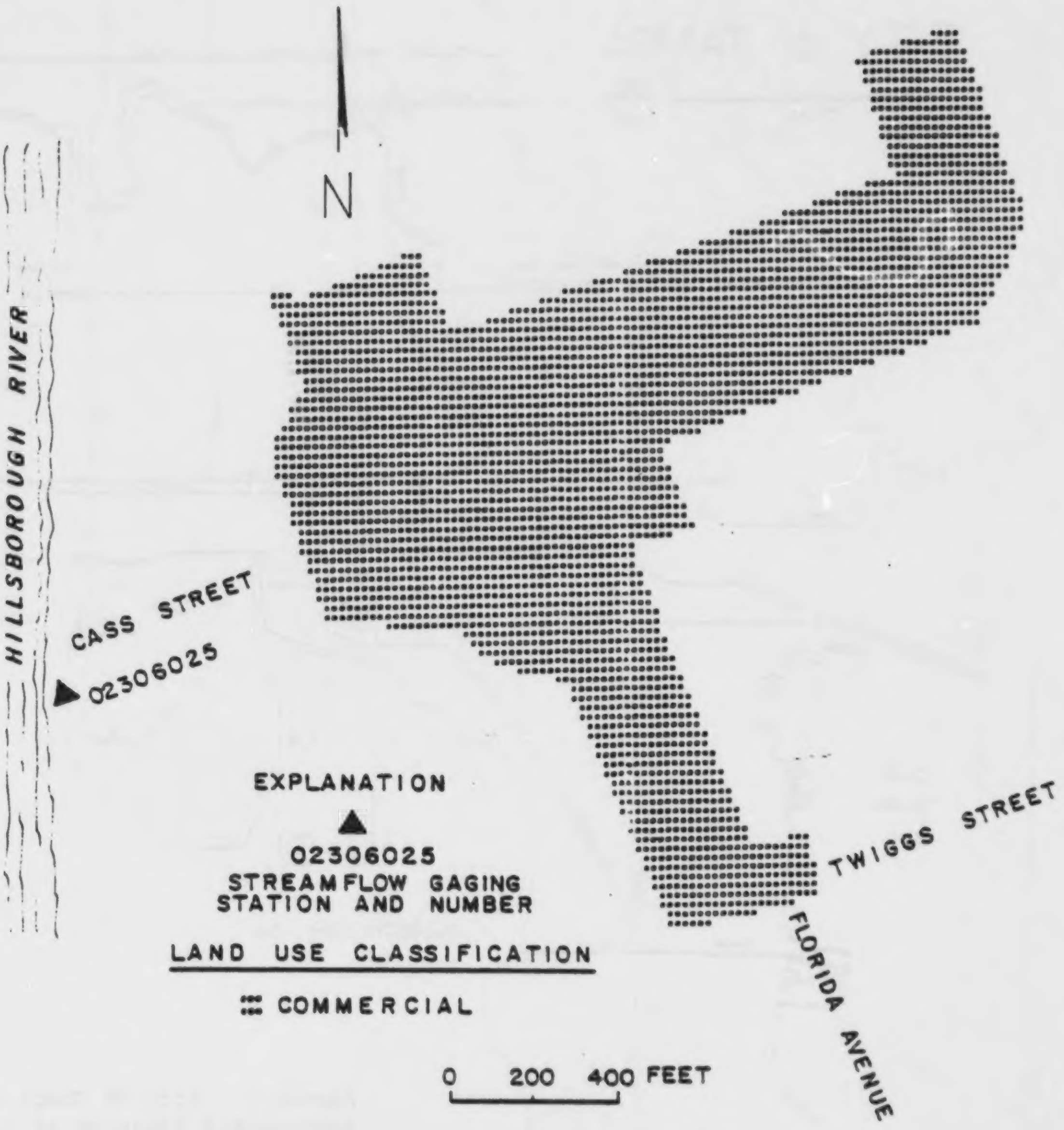
EXPLANATION
02306002
STREAMFLOW GAGING STATION AND NUMBER
02306002
RAIN GAGE AND NUMBER
LAND USE CLASSIFICATION
RESIDENTIAL
COMMERCIAL
02306002
ARTIC STREET
FLORIDA AVE.
0
1000 FEET

Figure 1. Land use in Artic Street Storm Drain watershed.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HILLSBOROUGH RIVER
CASS STREET
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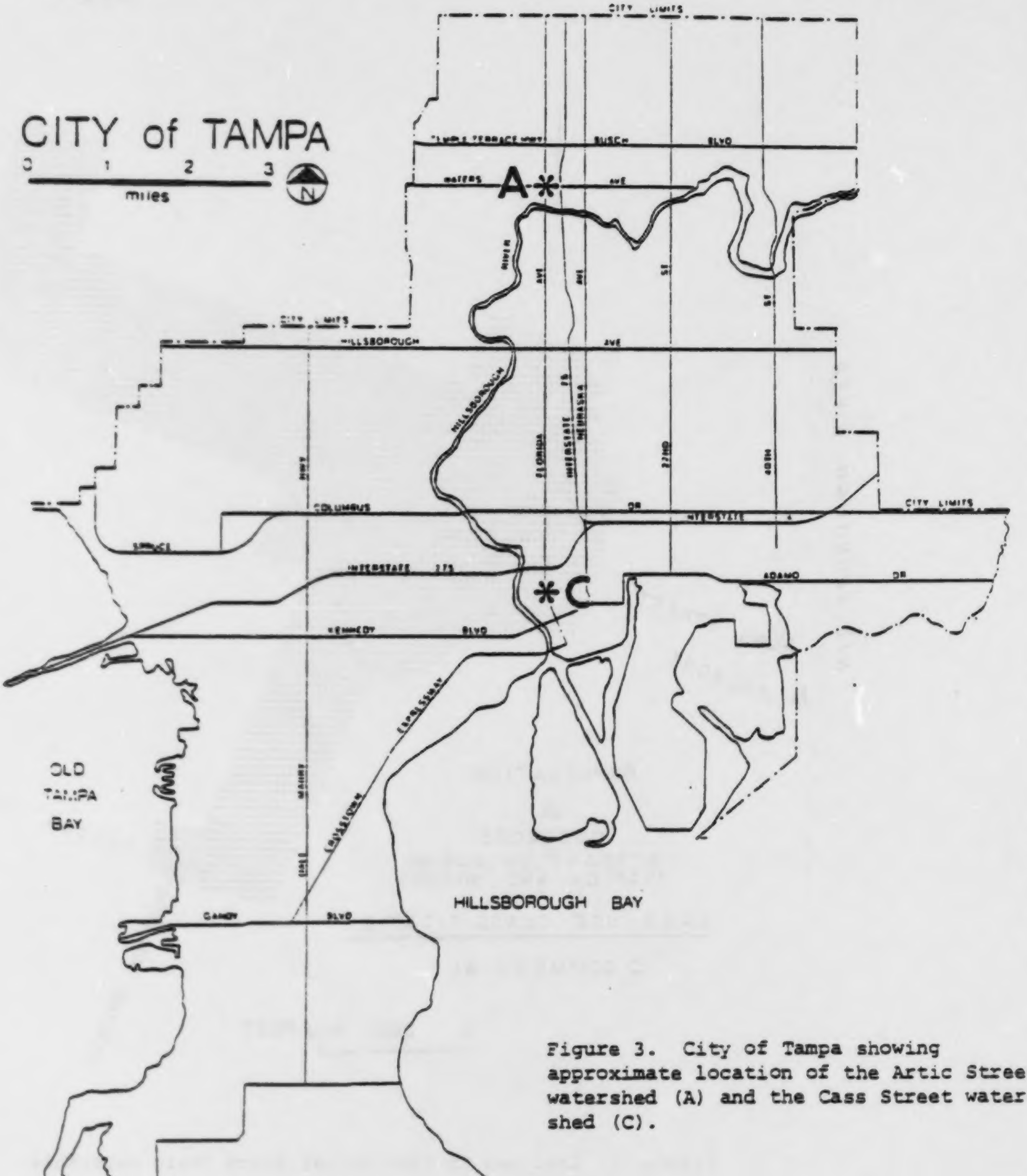
EXPLANATION
02306025
STREAMFLOW GAGING
STATION AND NUMBER
LAND USE CLASSIFICATION
COMMERCIAL
0 200 400 FEET
TWIGGS STREET
FLORIDA AVENUE

Figure 2. Land use in Cass Street Storm Drain watershed.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22ND
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DALE
COLUMBUS
DR
INTERSTATE 4
CITY LIMITS
SPRUCE
INTERSTATE 275
*C
ADAMO
DR
KENNEDY
BLVD
EXPRESSWAY
CROSSTOWN
MABRY
DALE
OLD
TAMPA
BAY
HILLSBOROUGH BAY
GANDY
BLVD
MAC DILL AIR FORCE BASE

Figure 3. City of Tampa showing approximate location of the Artic Street watershed (A) and the Cass Street watershed (C).

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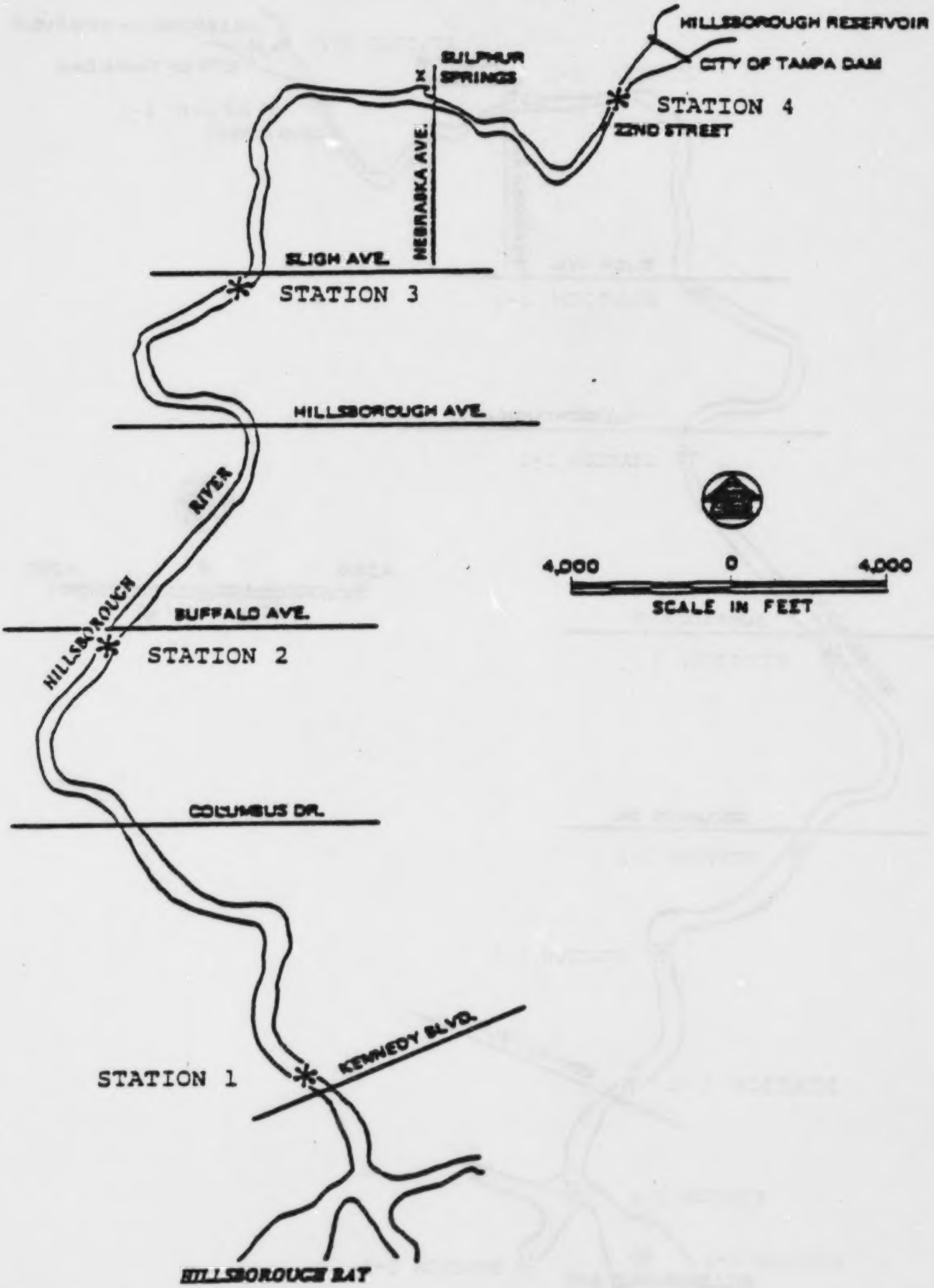
HILLSBOROUGH RESERVOIR
CITY OF TAMPA DAM
SULPHUR SPRINGS
STATION 4
22ND STREET
NEBRASKA AVE.
SLIGH AVE.
STATION 3
HILLSBOROUGH AVE.
HILLSBOROUGH RIVER
4,000
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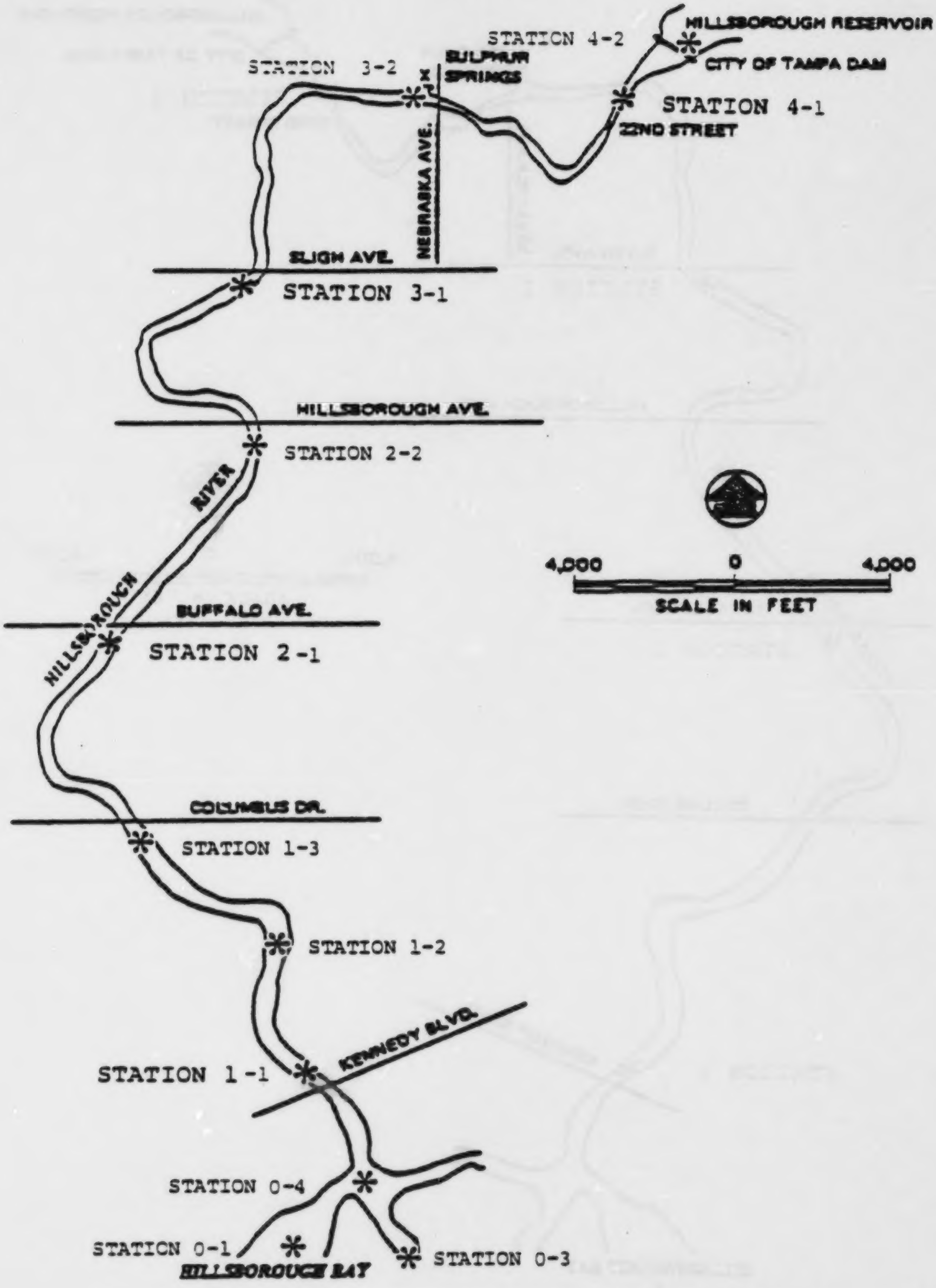
SCALE IN FEET
BUFFALO AVE.
STATION 2
COLUMBUS DR.
KENNEDY BLVD.
STATION 1
HILLSBOROUGH BAY

Figure 4. Plan of lower Hillsborough River showing sampling locations for biological studies.


HILLSBOROUGH RESERVOIR
STATION 4-2
CITY OF TAMPA DAM
STATION 3-2
SULPHUR SPRINGS
x
STATION 4-1
22ND STREET
NEBRASKA AVE.
SLIGH AVE.
STATION 3-1
HILLSBOROUGH AVE.
STATION 2-2
RIVER
4,000
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4,000
SCALE IN FEET
HILLSBOROUGH
BUFFALO AVE.
STATION 2-1
COLUMBUS DR.
STATION 1-3
STATION 1-2
KENNEDY BLVD.
STATION 1-1
STATION 0-4
STATION 0-1
STATION 0-3
HILLSBOROUGH BAY

Figure 5. Location of sampling stations for hydrocarbon studies. All statio s sampled for sediments; stations 1-1,1-3,3-1,0-1,0-2,4-2,4-1 sampled also for suspended particulate matter.

II. BENTHIC INFAUNAL AND EPIFAUNAL STUDIES

A. Introduction

The purpose of this investigation was to document quantitatively and qualitatively the distribution of benthic invertebrates along the Hillsborough River and any seasonal changes accompanying the shift from dry to wet seasons. These data were to serve as the first quantitative sampling of this part of the river system and as a guide in selection of organisms for subsequent or simultaneous bioassay studies on toxicity of stormwater runoff.

B. Methods

Quantitative benthic samples were taken at four sites along the Hillsborough River (Table 1) during the dry season (May 5, 1982) and the wet season (August 6, 1982). At each site, two cross-river transects perpendicular to the flow were established approximately 33 meters apart. Three samples were obtained along each transect, one at mid river and one approximately 5 meters from each shoreline. Six replicate samples were taken at each site with a 15.25 x 15.25 cm Ekman grab sampler. The contained material was washed through a 0.234 mm mesh screen and all retained material was narcotized with 0.15% propylene phenoxytol, stained with rose bengal and preserved in 10% formalin. Upon return to the laboratory, all animals were sorted from the samples using a dissecting microscope, identified to the lowest possible taxon (usually species) and counted.

During field sampling, the sediments obtained in the Ekman grabs were visually described. Surface water temperature was measured with a mercury bulb thermometer and surface salinity was measured with a hand-held refractometer.

Additionally, up to 4 Hester-Dendy multiple plate samplers were set out at each site (see Table 5). During the dry season, plate samplers were deployed on May 5 and collected on May 12, 1982, an in situ period of one week. During the wet season, samplers were deployed on August 6 and collected on August 20, an in situ period of two weeks. Upon collection, samplers were returned to the laboratory, dismantled, and all organisms washed from the plates and treated as above. Species were identified and relative abundance recorded.

Species saturation curves were constructed to document that the number of quantitative samples taken was adequate. Due to the late starting date of the project a set of preliminary samples to determine sample size adequacy was not taken. Instead, species saturation curves were calculated for both wet and dry season samples.

Data were summarized as: total number of species present; total number of individuals present (mean and S.D. of 6 samples/site); number of "freshwater" species; number of "estuarine" species; H' (Shannon-Weaver diversity index); and E (equitability = H'/H_{max}). The Shannon-Weaver Index represents the number of species collected relative to the total number of individual organisms collected, while the equitability index represents the distribution of individuals among the species present (see Krebs, 1972, pp. 500-536, for a discussion of diversity). These indices are most useful in the present study for comparisons of community composition at individual stations between wet and dry seasons.

C. Results

Station locations, temperature and salinity, and sediment descriptions are presented in Table 1 and Table 2. Sediments varied both from site to site and within sites with season. During the dry season, there was a gradual salinity gradient from Hillsborough Bay salinities (22 o/oo) at Station 1 to almost freshwater (3.5 o/oo) at Station 4. During the wet season, the river water was essentially freshwater.

Species saturation curves constructed for each site and each sampling period are presented in Figures 6 & 7. Since all curves reached an asymptote after 2 or 3 samples, six samples were more than adequate to describe the fauna.

The mean densities (and standard deviations) for all benthic invertebrates collected in the quantitative samples are presented in Table 3 and summarized in Table 4. During the dry season, the fauna at all but Station 4 was dominated by estuarine species. Among the dominant estuarine species represented were the polychaete, Laeonereis culveri, and the amphipod Grandidierella bonnieroides. Moving upstream, freshwater organisms, especially insect larvae, as well as the bivalve Corbicula manilensis, and the amphipods Gammarus palustris and Hyalella azteca, appeared in increasing abundance.

During the wet season, the total number of species decreased at all sites except Station 4. The density of individuals followed a similar pattern, with marked depression in the number of individuals accompanying the wet season shift in salinity and species (Note: the densities, H' and E values at Station 4 were roughly equal during dry and wet seasons).

The largest number of species collected (36) was at the mouth of the river (Station 1) during the dry season, indicating the importance of the influence of Hillsborough Bay and estuarine salinities. Transport of marine invertebrate larvae from the bay into the river during low river flow periods is likely responsible for the high occurrence of marine species at Station 1. The largest number of individuals collected was at Station 2 site during the dry season. The site was dominated by Laeonereis culveri and Grandidierella bonnieroides, both estuarine species commonly found in organically enriched sediments.

Species collected in Hester-Dendy multiple plate samplers tracked those collected in the benthic samples (Table 5). In addition, several small "fouling" species were added to the total faunal list. Many fewer polychaetes and more insects and crustaceans were collected by the Hester-Dendy plates.

The overall results present a rather typical picture of what would be expected in a system which seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. When under estuarine conditions, more individuals of more species are present than when under freshwater conditions. The system must constantly be readjusting as salinities change. To better understand the dynamics of the river biota, the changes in salinity, species density and species composition need to be considered with regard to wet season and dry season values (Table 4). Station 1 appears to be most affected by the dry season to wet season transition with notable reductions occurring in salinity, total number of species, total density, number of marine species present, species diversity and equitability. Station 4 displayed the least change in these parameters following the dry to wet season transition. The ability of sediments to buffer water column salinity changes and to maintain higher interstitial salinities probably account for the presence of estuarine species further upriver than might be expected based on water column salinities alone. In this study, only surface salinities were measured. A saline wedge (Metcalf and Eddy, 1983b) underlying the surface freshwater and moving upriver with rising tides would also help buffer benthic organisms against freshwater flow.

Table 1: Site and sample locations along the Hillsborough River at which quantitative benthic invertebrate samples were collected. At each site, two transects approximately 33 meters apart were sampled. Samples were taken approximately 5 meters from each shore and at mid-river. Six 15.25 X 15.25 cm Ekman grabs were obtained at each sampling site.

DESIGNATION **DESCRIPTION**

Station 1 Opposite the University of Tampa boat dock

DRY SEASON Temp. = 24°C Salinity = $22^{0}/_{00}$

Upstream transect
East shore: depth 1.3m
sediment = sand, detritus
Mid-river: depth = 3.6m
sediment = sand, shell, detritus
West shore: depth 1.8m
sediment = sand, shell, detritus

Downstream transect
East shore: depth = 3.0
sediment = sand,shell, detritus
Mid-river: depth 3.8 m
sediment = sand,shell, detritus
West shore: depth 1.7 m
sediment = detritus

WET SEASON Temp. = 29°C Salinity = $2^{0}/_{00}$

Upstream transect
East shore: depth 2.5 m
sediment = sand, shell, detritus
Mid-river: depth 4.8 m
sediment = sand, shell, detritus
West shore: depth 1.2 m
sediment = sand, shell, detritus

Downstream transect
East shore: depth 3.0 m
sediment = detritus, sand, shell
Mid-river: depth 4.0 m
sediment = shell, sand, detritus
West shore: depth 1.3 m
sediment = detritus

Station 2 Just north of River Club Apartments, Buffalo Avenue.

DRY SEASON Temp. = 24°C Salinity = $14^{0}/_{00}$

Upstream transect
East shore: depth 2.0 m
sediment = detritus, little sand
Mid-river: depth 3.8 m
sediment = detritus, shell
West shore: depth 1.2 m
sediment = detritus, sand

Downstream transect
East shore: depth 1.9 m
sediment = shell, detritus, sand
Mid-river: depth 3.5 m
sedicment = shell, detritus, sand
West shore: depth 0.3 m
sediment = clean sand

WET SEASON Temp. = 28°C Salinity = $1^{0}/_{00}$

Upstream transect
East shore: depth 2.0 m
sediment = detritus
Mid-river: depth 4.2 m
sediment = detritus, shell
West shore: depth 1.2 m
sediment = sand, detritus

Downstream transect
East shore: depth 2.0 m
sediment = detritus, shell, sand
Mid-river: depth 4.0 m
sediment = detritus, sand
West shore: depth 1.0 m
sediment = detritus, sand

Station 3 Either side of the Sligh Ave. bridge

DRY SEASON Temp. = 23°C Salinity = 10 $/_{oo}$

Upstream transect
East shore: depth 2.5 m
sediment = detritus, sand
Mid-river: depth 3.0 m
sediment = shell, rock
West shore: depth 2.4 m
sediment = shell, detritus

Downstream transect
East shore: depth 1.0 m
sediment = shell, sand, pebbles
Mid-river: depth 3.3 m
sediment = rock bottom
West shore: depth 1.1 m
sediment = shell, detritus, pebbles

WET SEASON Temp. 28°C Salinity = 2 $^{o}/_{oo}$

Upstream transect
East shore: depth 2.2 m
sediment = detritus, shell
Mid-river: depth 4.0 m
sediment = detritus, shell, sand
West shore: depth 2.5 m
sediment = sand, detritus

Downstream transect
East shore: depth 1.7 m
sediment = detritus, shell
Mid-river: depth 4.0 m
sediment = detritus, sand
West shore: depth 1.3 m
sediment = detritus, sand, shell

Station 4 Between 22nd street bridge and city dam

DRY SEASON Temp. = 22°C Salinity - 2.5$^{o}/_{oo}$

Upstream transect
East shore: depth 2.1 m
sediment - clay, shell, detritus
Mid-river: depth 3.2 m
sediment = sand, pebbles
West shore: depth 1.0 m
sediment = detritus, shell

Downstream transect
East shore: depth 1.3 m
sediment = moss
Mid-river: depth 0.8 m
sediment = moss
West shore: depth 1.0 m
sediment = rocks, plants

WET SEASON Temp. 28°C Salinity = 1$^{o}/_{oo}$

Upstream transect
East shore: depth 2.5 m
sediment = rock, pebbles
Mid-river: depth 1.0 m
sediment = plants, shell
West shore: depth 1.0 m
sediment = detritus, sand

Downstream transect
East shore: depth 2.5 m
sediment = shell, detritus
Mid-river: depth 2.0 m
sediment = rock, sand, pebbles
West shore: depth .75 m
sediment = rock, sand, detritus

Table 2: Temperature (°C) and Salinity ($^o/_{oo}$) at each sampling location, both wet and dry season.

STATION	DRY SEASON Temp	DRY SEASON Salinity	WET SEASON Temp	WET SEASON Salinity
1	24	22	29	2
2	24	14	28	1
3	23	10	28	2
4	22	3.5	28	1

TABLE 3: Mean densities of benthic invertebrates per 15.25 X 15.25 cm Eckman grab quantitative samples at four stations along the Hillsborough River (number of samples/site = 6; number in parentheses - standard deviation).

Freshwater species are indicated by a *; estuarine/marine species by at +.

Species	Station 1		Station 2		Station 3		Station 4	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
POLYCHAETA								
Polydora ligni+		.33(.82)	.50(.84)		.33(.82)			
Polydora juveniles+	2.0(3.2)							
Pectinaria gouldii+	1.0(.67)							
Nereis succinea+	3.7(2.3)		.33(.81)					
near Nicon sp.+		.50(1.2)	13.2(23.7)	.17(.41)	3.5(5.0)			
Laeonereis culveri+			108.8(239.2)	1.8(1.7)	5.7(9.8)	6.0(5.9)	9.8(19.9)	.17(.41)
Mediomastus californiensis+	23.8(26.6)							
Capitella capitata+		1.0(2.0)		7.3(15.2)				
Heteromastus filiformis+		1.6(4.1)						
Phyllodoce arenae+	.83(.15)							
Eteone heteropoda+			.17(.41)					
Glycinde sp.+	1.7(1.5)							
Glycera americana+	.33(.51)							
Mellina maculata+	1.8(2.1)							
Parahesione luteolata+	.33(.82)							
Scoloplos rubra+	.33(.52)							
Spiochaetopterus costatus+	33(.81)							
Nereis acuminata+			.33(.81)					
Nereid juvenille+				34.0(59.6)				
Syllid sp.+	.50(1.2)							
Megalomma bioculatum+	.67(1.2)							
Branchiomma nigromaculatum+	.17(.41)							
Terebella sp.+	.17(.41)							
Isolda puchella+			.17(.41)					
MOLLUSCA								
Amygdalum papyra+	.67(1.2)							
Mulinia lateralis+	.17(.40)							
Mytilopsis leucophaeta*		53.5(74.0	.67(1.6)	3.2(4.6)	1.5(1.8)	11.2(13.6)	.83(1.3)	.50(112)
Lyogyrus sp.*		.83(1.2)	18.2(39.4)		.33(.52)	4.0(1.6)		5.8(9.3)
Polymesoda carolinae?*				.17(.41)				

Corbicula manilensis*	.17(.40)				20.8(32.0)	140.8(192.7)	20.8(17.8)	
Graulus*								.17(.11)
Unid. bivalve+	.33(.81)							
Crepidula sp.+	.17(.40)							
Nudibranch sp.+	.17(.40)							
Planorbid sp.*								.17(.40)
CRUSTACEA								
Ampelesca verilli+	1.2(1.3)							
Grandidierella bonnieroides+	19.0(23.0)	.83(2.0)	233.8(440.5)	12.3(20.3)	51.3(103.3)	20.12(16.0)	.33(.82)	
Melita nitida+	5.3(13.1)							
Gammarus palustris*							57.3(114.7)	6.8(7.4)
Hyalella azteca*							15.8(37.8)	17.3(41.5)
Edotea montosa+	.33(.52)	1.0(2.0)	1.7(3.6)					
Cyathura polita+			.50(1.2)					
Munna sp.*						1.2(2.0)		
Cyclaspis varians+	16.7(15.9)							
Campylaspis sp.+			5.7(10.1)	2.2(5.3)				
Tanaid sp.+	.33(.81)					.17(.41)		
Mysidopsis bigelowi+	3.5(4.8)		4.2(4.2)	.83(1.3)	1.7(2.6)	.33(.82)		
Pagurus sp.+	.33(.81)							
Neopanope texana+	.33(.81)		4.2(5.0)	.17(.41)				
Callinectes sapidus+					.17(.41)			
Ostracod spp+*				4.5(8.3)		2.3(5.2)		50.2(117.1)
INSECT LARVAE								
Enallagma sp.*							.50(.84)	
Negomphodes ambigua*							.17(.41)	
Peltodytes sp.*								.83(2.0)
Chironomus sp.*		.17(.40)						
Chironomus carus*			1.67(3.2)		6.8(16.7)	2.8(4.8)		.17(.41)
Cryptochironomus fulvus*			.17(.41)			.33(.82)		1.2(1.9)
Pseudochironomus sp.*								.17(.41)
Procladius sp.*		.50(1.2)	5.7(7.7)			2.3(5.2)	.67(1.6)	
Glyptotendipes sp.*								.33(.82)
Dicrotendipes sp.*								.33(.82)
Polypedilum halterale*			3.0(4.2)			.83(1.2)		.83(1.2)
Chaoborus punctipennis*			1.0(1.26)			.17(.41)	.67(1.0)	

MISC								
Rhynchocoela spp.†*	1.2(1.6)						6.2(7.3)	
Flatworm spp.*†	1.5(1.4)	.33(.82)	23.8(27.9)	1.0(2.4)			16.3(21.7)	2.5(4.3)
Oligochaeta spp.†*		.33(.82)		5.8(8.3)	16.0(12.9)		21.3(50.8)	29.3(44.6)
Leech sp.*								.33(.52)
Hydroid (solitary)†			.17(.41)					
TOTAL NUMBER OF SPECIES	36	13	23	14	12	14	13	18
TOTAL NUMBER OF INDIVIDUALS	252.3	146.9	468.8	67.1	109.0	192.4	101.0	100.8

Table 4: Summary of quantitative benthic samples allong the Hillsborough River. H' = Shannon-Weaver Diversity Index; E - Equitability (H'/H_{max}). Total Density = mean # of individuals/15.25 X 15.25 cm Ekman Grab.

TIME OF SAMPLING	STATION	TEMP (°C)	SALINITY (°/oo)	TOTAL # SPECIES	TOTAL DENSITY	# MARINE SPECIES	# FRESH WATER SPECIES	H'	E
DRY SEASON									
	1	24	22	36	252.3	35	1	2.53	.49
	2	24	14	23	468.8	16	7	1.62	.37
	3	23	10	12	109.0	7	5	1.92	.52
	4	22	2.5	13	101.0	2	11	2.48	.62
WET SEASON									
	1	29	2	13	146.9	9	4	.942	.25
	2	28	1	14	67.1	10	4	2.96	.76
	3	28	2	14	192.4	6	8	2.94	.75
	4	28	1	18	100.8	1	17	2.45	.59

TABLE 5: Species collected in Hester-Dendy plate samplers along the hillsborough River. X = present; * = present in high abundance for that taxon.

SPECIES	LOCATION							
	Station 1		Station 2		Station 3		Station 4	
	Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Number of Samplers	3	3	3	4	3	4	2	2
POLYCHAETA								
Capitellides jonesi	X							
near Nicon sp.	X							
Streblospio benedicti	*							
Polydora ligni	*		X		X			
Neanthes arenaceodentata	X							
Neanthes succinea	X							
Autolytus cornutus	X							
Spirorbis spirillum			X		X			
Laeonereis culveri				X	X			
MOLLUSCA								
Mytilopsis leucophaeta	*	*	*	*	*	X		
Leucoplax diaphenus		X		X		X		X
Amygdalyum papyra	X							
Lyogyrus sp.				X			X	
Helisoma sp.				X				
Nudibranch sp.	X							
CRUSTACEA								
Grandidierella bonnieroides	*		X		*		X	
Hyalella azteca		X		X		X	X	X
Orchestia sp.	*		X	X				
Munna sp.						X		
Gammarus palustris							*	
Caprellid sp.	X							
Tanaid sp.	X			X		X		
Neopanope texana	X			X		X		
Palaemonetes sp.	X	X	X					
Crangonyx sp.	*	X	X					
Mysis sp.					X			
Barnacle juv.	X	X	X				X	

Cassidinea lunifronds		X	X					
Ostracod spp.		X						
Cladocera spp.				X		X		X
INSECT LARVAE								
Enallagma sp.		X		X		X		X
Chironomus carus		X		X	X	X	X	
Chironomus sp.		X						
Parachironomus sp.		X						
Pseudochironomus sp.				X		X		
Procladius sp.		X		X		X		
Glyptotendipes sp.						X		
Dicrotendipes sp.		X		X		X		
Dicrotendipes leucoscelis			X		X		X	
Dicrotendipes nervosus								X
Polypedilum convictum		XX		X				
Polypedilum illinoense		X				X		X
Dianesa sp.		X						
Ischnura posita				X			X	
Stenonema proxima				X				
Cyrnellus sp						X	X	X
Paroponyx sp						X		
Baetis intercalaris					X	X	X	
Anomalagrion hastatum							X	
Callibaetis floridanus							X	
Cheumatopsyche sp.								X
unid. Coleoptera							X	
MISC								
Rhynchocoela sp.							X	
Flatworm spp.	X		X	X	X	X	X	
Oligochaeta spp.		*		*	*	*	*	*
Hydroid (solitary)			X		X		X	
Hydroid (colonial)	X				X			
Hydra sp. I				X		X		
Hydra sp. II				X				
TOTAL NUMBER OF SPECIES	21	19	13	22	12	19	17	9

Figure 6. Species saturation curves for wet and dry season samples at Stations 1 & 2 (Univ. of Tampa and Riverclub Apartments.

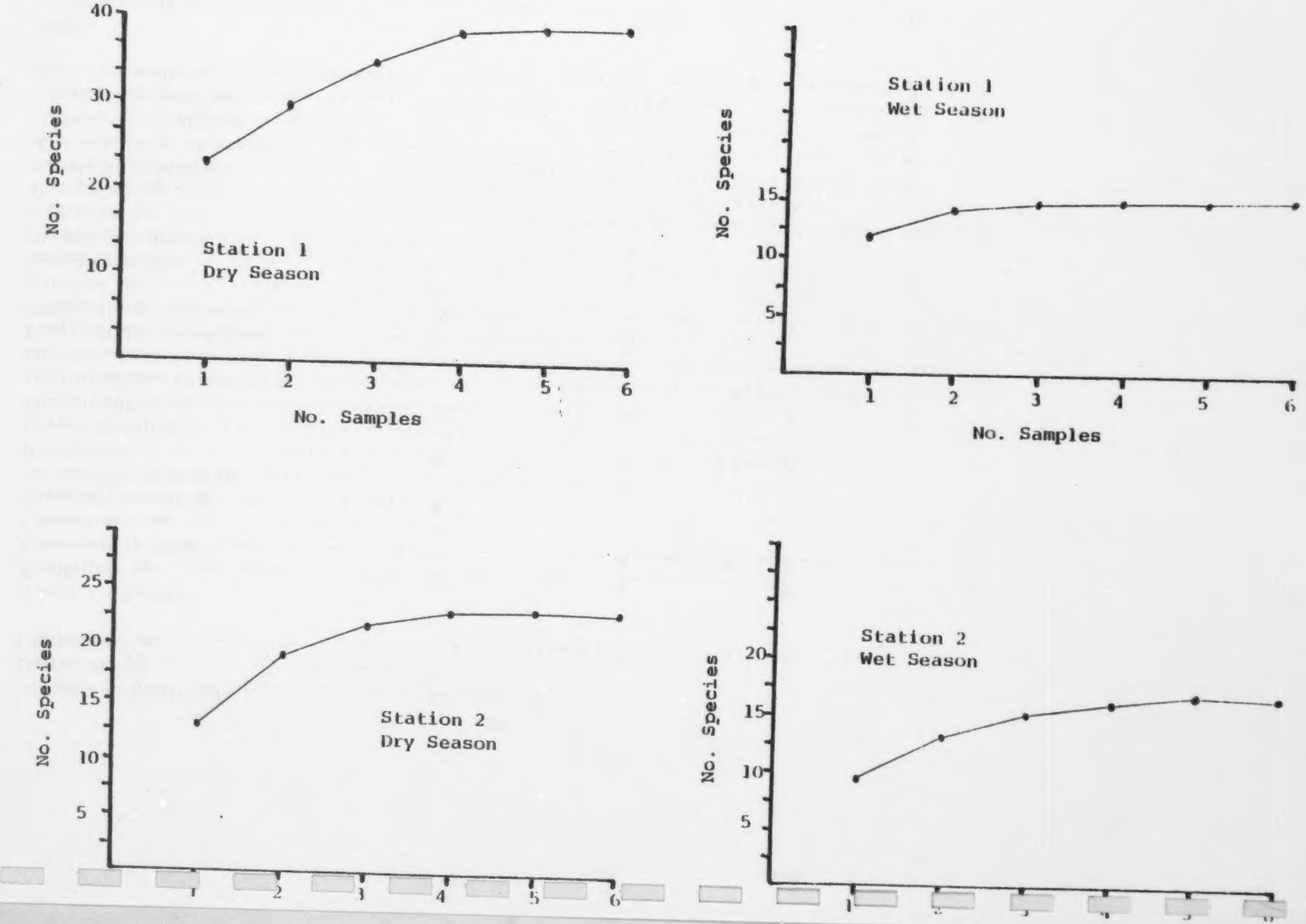

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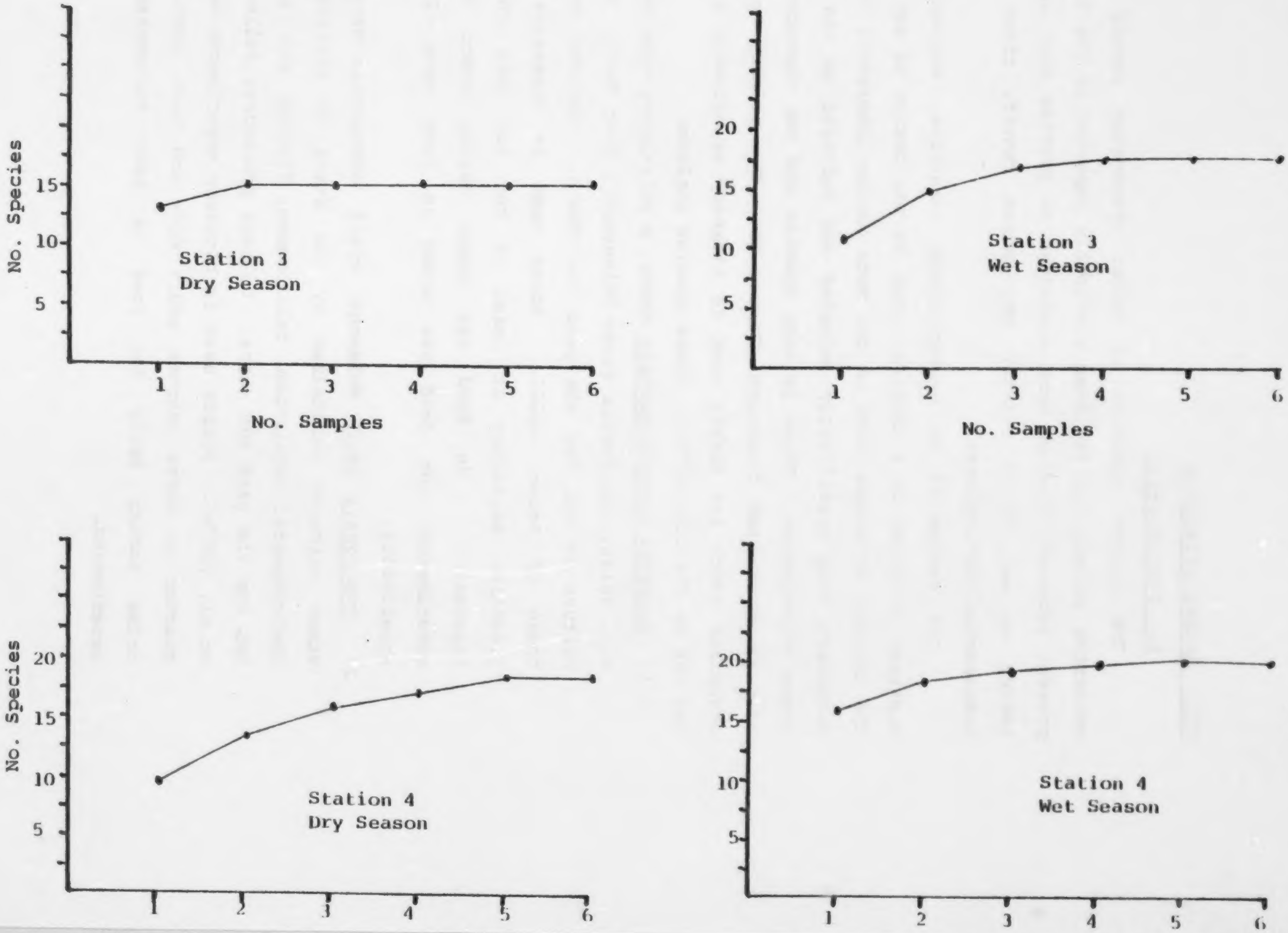
Figure 7. Species saturation curves for wet and dry season samples at Stations 3 & 4 (Sligh Bridge and 22nd Street).



III. ANIMAL BIOASSAYS

A. Introduction

The direct toxicity of urban stormwater runoff to marine or estuarine animals has not been previously reported in the literature. The present bioassay studies were conducted to provide this information with regard to wet season runoff, dry season runoff, river sediments and resuspended particulates.

The choice of an appropriately sensitive, ecologically relevant bioassay organism is a critical step in the design of any toxicity test. The bioasay organisms used in the Mote Marine Laboratory (MML) stormwater bioassays were specifically selected and cultured in the laboratory for these experiments. Three primary species and two secondary species were used in stormwater bioassays (Figure 8). The primary species represent organisms which are widely used in bioassay experiments and are approved for use by EPA/COE (1977). These species include:

1) Neanthes arenaceodentata Moore, a polychaete worm obtained from Dr. D.J. Reish, California State University, Long Beach, has been kept in culture at MML for the past two years. Culture procedures follow those of Reish (1980). Worms used in bioassays were immature juveniles measuring at least 16 but not more than 30 setigers (segments). No food was added during short term (96 hour) experiments, but food was added in long term (28 day) chronic experiments.

2) Mysidopsis bahia Molenock, mysid crustacenas were obtained from stock cultures maintained by the State of Florida Department of Environmental Regulation, Tallahassee, Florida, and kept in culture at MML for the past two years. Culture procedures follow those of Nimmo et al. (1976). Mysids used in bioassay experiments were immature one quarter to three quarter adult size and were provided with living brine shrimp daily for food in both stormwater and sediment experiments.

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3) Cyprinodon variegatus (Lacepede), an estuarine fish, was obtained from Sarasota Bay near MML and kept in culture for the past two years. Culture procedures for maintaining various life stages of these fish were adopted from Standard Methods (1980). Naturally spawned juvenile fish between the age of 12 and 60 days post spawning were used in all bioassay experiments. Fish were not fed during short term experiments but were given living brine shrimp during long term tests.

The secondary species used in bioassay experiments represent seasonally available organisms or animals with a less well defined toxicological background than the primary species and include:

1) Menippe mercenaria, the stone crab, was collected as gravid females from the Gulf of Mexico and allowed to spawn in the laboratory. First through third stage zoea were used in bioassay experiments and were provided with living brine shrimp for food in all experiments.

2) Pseudocyclops sp., a calanoid copepod was isolated from the MML seawater system and cultured in the laboratory. Copepods were not fed during experiments (only short term tests were run) and adults were used in all tests.

B. Methods

Stormwater Bioassays

Stormwater samples used in bioassay experiments were collected by City of Tampa personnel from the Artic Street outfall on July 16 and October 14, 1982 and from the Cass Street outfall on January 21, 1983. These three stormwater samples can be considered as wet season samples. A single rain event sampled on May 5, 1983 from the Artic Street basin was considered to represent dry season runoff. One portion of this sampling, the first flush of runoff, was collected and stored separately for chemical analysis. Stormwater samples represented a composite of numerous subsamples collected throughout the rainfall event and were stored at $4^{o}C$ in linear polyethylene containers following collection. Representative samples of this stormwater were adjusted to an appropriate salinity with Instant Ocean salts prior to experiments. Short term (96 hr) bioassays were static, while long term bioassays were static with periodic replacement of test solutions. Survival rate was the parameter measured in short term experiments, while growth rates (in setigers for *Neanthes* and millimeters for *Cyprinodon*) were measured in long term tests.

Suspended Particulate Phase Bioassays

Equal portions of sediment from the three Hillsborough River collection sites were weighed out and mixed with seawater of the appropriate pH and salinity in a ratio of four parts water to one part sediment by weight. This mixture was stirred continuously for 30 minutes and then allowed to settle undisturbed for one hour. The supernatant remaining after the settling period was siphoned off into the appropriate test container and used as suspended particulate phase (SPP) solution. Test solutions with mysids and fish were aerated to maintain acceptable levels of dissolved oxygen throughout the experiment. Bioassays with worms did not require aeration.

Seawater that was mixed with sediment to produce the SPP was made up with Instant Ocean salts in distilled-deionized water. The pH of this seawater was adjusted to the appropriate value using 10% HCl prior to mixing with sediment. Control treatments were composed of seawater identical in pH and salinity to the water used to make the SPP.

Test conditions for the SPP bioassays included the following combinations: 1) 20 o/oo and pH 8; 2) 15 o/oo and pH 6; 3) 20 o/oo and pH 6; and 4) 15 o/oo and pH 8. Each of these combinations was tested with *Neanthes arenaceodentata*, *Mysidopsis bahia* and *Cyprinodon variegatus*. Survival rate alone was monitored in tests with *Mysidopsis*, while survival and growth rates were determined for *Neanthes* and *Cyprinodon*.

Sediment Bioassays

Whole sediment bioassays were conducted with *Neanthes*, *Mysidopsis* and *Cyprinodon* using a composite sediment sample composed of equal portions from each of the three sampling sites. For *Neanthes*, an infaunal species, the worms were placed in test chambers containing control sediment from New Pass, Sarasota and allowed to acclimate for two days. Composite test sediment from the Hillsborough River was then added to half the chambers, while an equivalent amount of control sediment was added to the other half. Five replicate chambers with five worms each were exposed to control and experimental treatments for 14 days.

For *Mysidopsis*, an epifaunal species, test animals were placed inside screened containers which were in turn placed inside larger chambers containing either control sediment or Hillsborough River sediment. Fifteen mysids were used in each of the control and experimental treatments. Exposure lasted for 96 hours.

Cyprinodon tests with whole sediment involved procedures similar to those used with *Neanthes*. Half the fish were exposed to Hillsborough River sediment on top of control sediment, while the remainder were exposed to control sediment only. Twenty five fish per treatment were used.

Worms, mysids and fish were provided with food during the course of the experiments.

Chemical Analyses

Chemical analyses were performed on each of the five stormwater samples shortly after their arrival at MML. Heavy metal determinations were made on an Instrumentation Laboratory atomic absorption spectrophotometer using standard addition techniques. Analyses were performed on whole, unfiltered stormwater. A total hydrocarbon analysis was performed on the July 1982 sample using a Varian 6000 gas chromatograph with a 30 m capillary column coated with SE30 and run at 100-280 °C. Detection was by flame ionization using splitless injection. (See Section VIII, below.)

C. Results

A total of 78 animal bioassays were completed during the course of this project. Thirty of these bioassays involved stormwater samples; 17 with wet season runoff and 13 with dry season runoff. The remaining 48 bioassays involved single or multiple heavy metals, sediment tests or suspended particulate phase experiments. In all cases, statistical significance was determined using the Students' t Test comparison of mean survival or growth rate between control and experimental treatments or a single classification ANOVA (Sokal & Rohlf, 1973).

Wet Season Runoff Bioassays

Results of initial acute bioassays using July 1982 stormwater are presented in Figures 9-13. No significant differences were observed in 96 hour survival rates for any of the five test species between control treatments and three dilutions of stormwater (10%; 50%; and 100% stormwater). October 1982 stormwater was tested in 96 hour acute bioassays using *Neanthes* and *Cyprinodon* as test organisms and showed no significant differences in survival between control and experimental treatments (Figure 15). January 1983 stormwater was tested in 96 hour bioassays using *Neanthes* and *Mysidopsis* and showed no significant reduction in survival for stormwater treatments (Figure 16).

Long term chronic bioassays for wet season runoff were undertaken using July stormwater. *Neanthes* and *Cyprinodon* were tested in these experiments with survival and growth rates measured in three dilutions of stormwater plus controls. The results of the chronic experiments with *Neanthes* are presented in Figures 14 and 17. The growth rates between treatments in Figure 14 are significant; however, these differences are due to intraspecific competition and predation rather than stormwater concentration. The same experiment was repeated except that each worm was held in a separate dish (Figure 17) and the results indicate no significant differences between treatments. All subsequent long term bioassays employed separate dishes for each worm.

The results of chronic bioassays with Cyprinodon are presented in Figures 18 and 19. The initial 28 day growth experiment (Figure 18) resulted in a significant difference between the 50% stormwater and control treatments. However, the survival rate in 50% and 100% stormwater was lower than controls and this may have influenced the results. The experiment was repeated (Figure 19) using the same procedures and this time survival in all treatments was 100%. In this second experiment, there were no significant differences in growth rates between treatments. As a general procedure, when control survival exceeded 10% the experiment was repeated.

The effects of salinity shock (rapidly lowered salinity) in combination with wet season stormwater exposure were tested in acute 96 hour bioassays using Mysidopsis and Neanthes. In these experiments, test animals were rapidly transferred from their normal culture salinity (25 o/oo for Mysidopsis and 30 o/oo for Neanthes) to test solutions of 15 o/oo salinity. Control treatments consisted of standard culture seawater diluted to 15 o/oo with distilled deionized water. Two dilutions of stormwater were tested with Mysidopsis (Figure 21) and three dilutions were tested with Neanthes (Figure 20). The survival rates for both species after 96 hours showed no significant differences between control and experimental treatments. After 7 days of exposure, Mysidopsis had a significantly lower survival rate in 100% stormwater than in controls. However, this type of exposure to stormwater would not be likely to occur under natural conditions in the Hillsborough River.

Dry Season Runoff Bioassays

Dry season runoff, collected on May 4, 1983 from the Artic Street watershed, was tested in acute bioassays with Neanthes, Mysidopsis, Cyprinodon, and Pseudocyclops. Chronic bioassays with this stormwater were conducted with Neanthes and Cyprinodon.

Acute bioassays with dry season runoff were carried out at two salinities (20 o/oo and 15 o/oo) and three stormwater concentrations (10%, 50%, 100%). In tests using Cyprinodon, no reduction in survival was evident in 20 o/oo salinity tests. At 15 o/oo, survival was lowered in 100% stormwater; however the reduction in survival was not significant

(Figure 22).

Acute bioassays with Neanthes resulted in no survival reduction at 20 o/oo but produced a significant reduction in 100% stormwater at 15 o/oo salinity (Figures 23 and 24). Similar tests with Mysidopsis produced a progressive reduction in survival with increasing stormwater concentration at both 20 o/oo and 15 o/oo salinitiies; however these reductions were not statistically significant (Figures 25 and 26).

Neanthes and Mysidopsis were tested in acute bioassays with dry season stormwater which had been filtered through a 0.45 u Millipore filter. These tests were conducted at 15 o/oo salinity and results are presented in Figures 27 and 28. Reduced survival was observed in Mysidopsis tests at the highest stormwater concentration but was not significant. Neanthes bioassays resulted in significant reductions in survival at 50% and 100% stormwater concentrations.

Acute bioassays using Pseudocyclops resulted in significantly reduced survival at both 25 o/oo (normal culture salinity) and 15 o/oo salinities in the 100% stormwater concentration.

Chronic bioassays with dry season runoff were undertaken with Neanthes and Cyprinodon in which growth rates were measured in three stormwater concentrations plus controls. Neanthes was tested at 20 o/oo salinity resulting in no significantly reduced growth rate after 28 days exposure and at 15 o/oo salinity resulting in a significantly depressed growth rate in 100% stormwater after 7 days (Figure 29). Cyprinodon was exposed to stormwater at 20 o/oo salinity for 21 days and showed no significant reduction in growth rate. Tests at 15 o/oo salinity were not attempted due to depletion of stormwater supplies.

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Figure 9. 96 hour survival rate for Neanthes arenaceodentata exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment

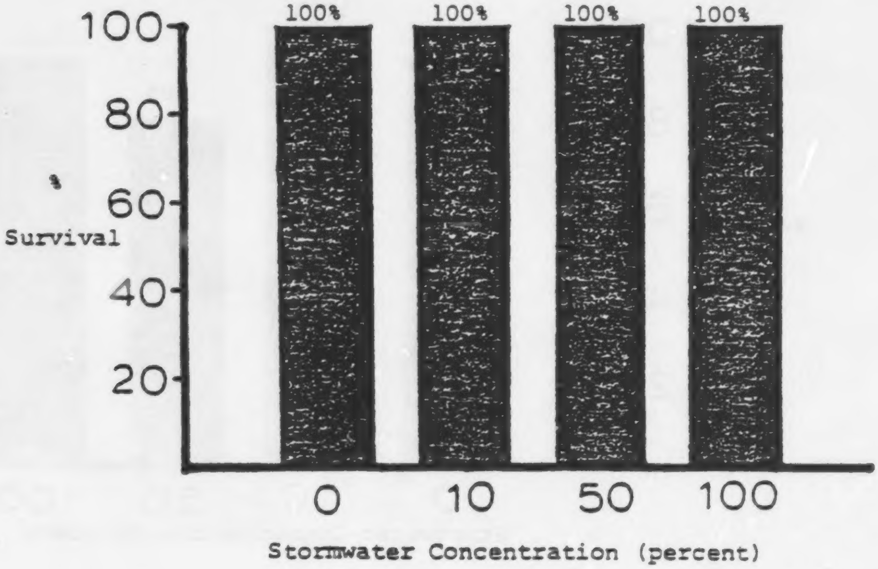

Figure 10. 96 hour survival rate for Cyprinodon variegatus exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment

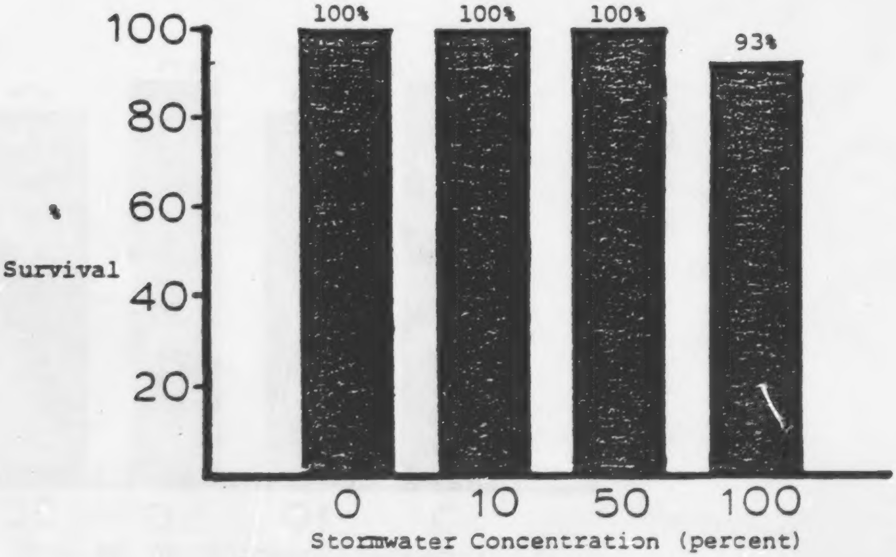

Figure 11. 96 hour survival rate for Mysidopsis bahia exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment

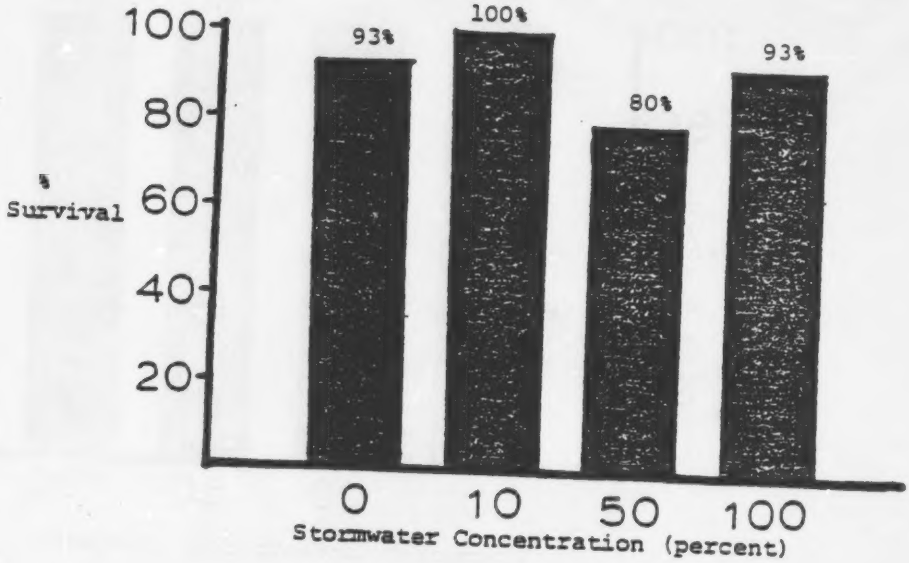

Figure 12. 96 hour survival rate for Pseudocyclops sp. exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 18/treatment

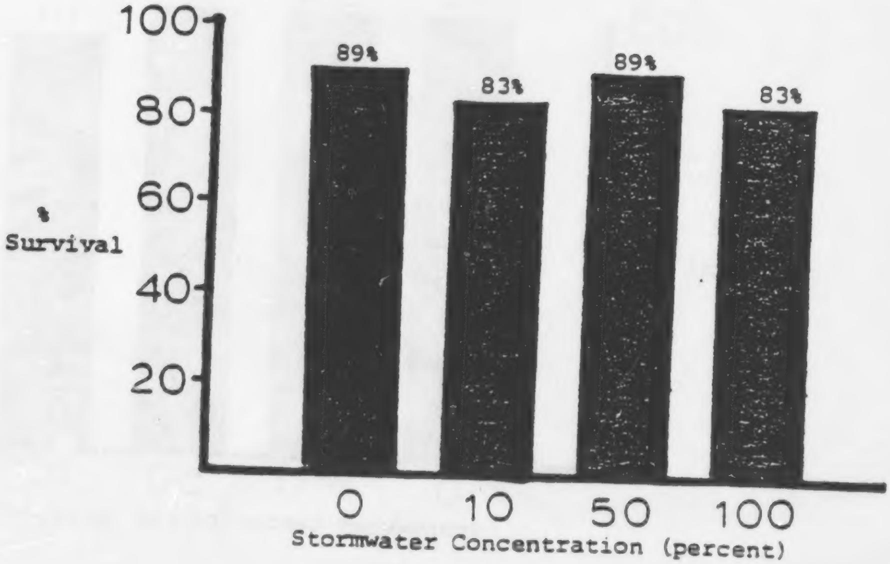

Figure 13. 96 hour survival rate for *Menippe mercenaria* exposed to dilutions of July stormwater.
T = 23°C
S = 30 o/oo
n = 15/treatment

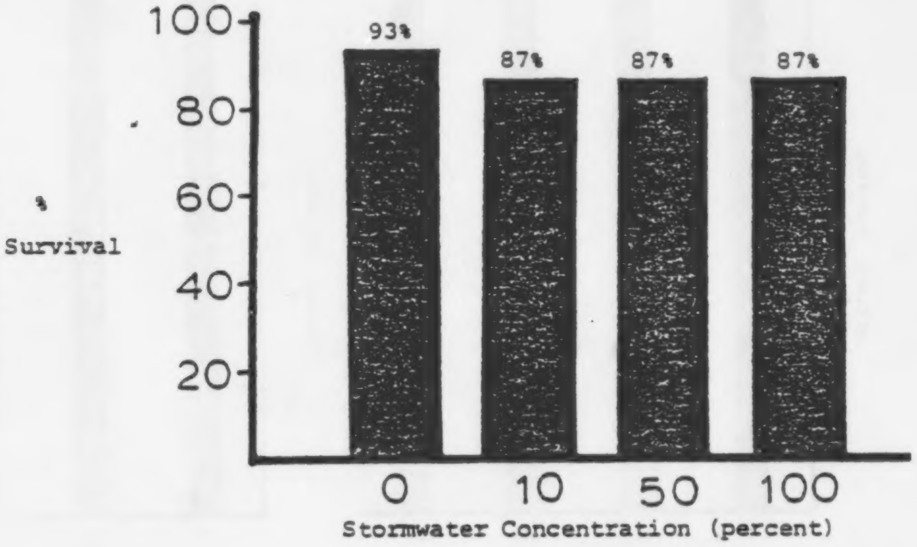

Figure 14. 28 day growth of *Neanthes arenaceodentata* exposed to dilutions of July stormwater.
T = 25°C
S = 25 o/oo
n = 15/treatment (5 worms per dish)

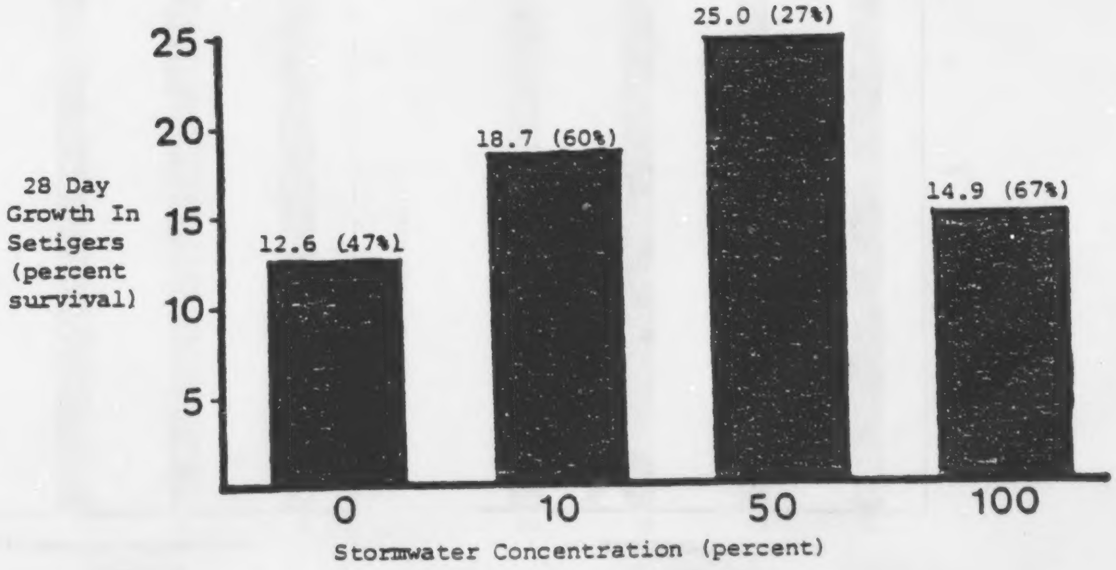

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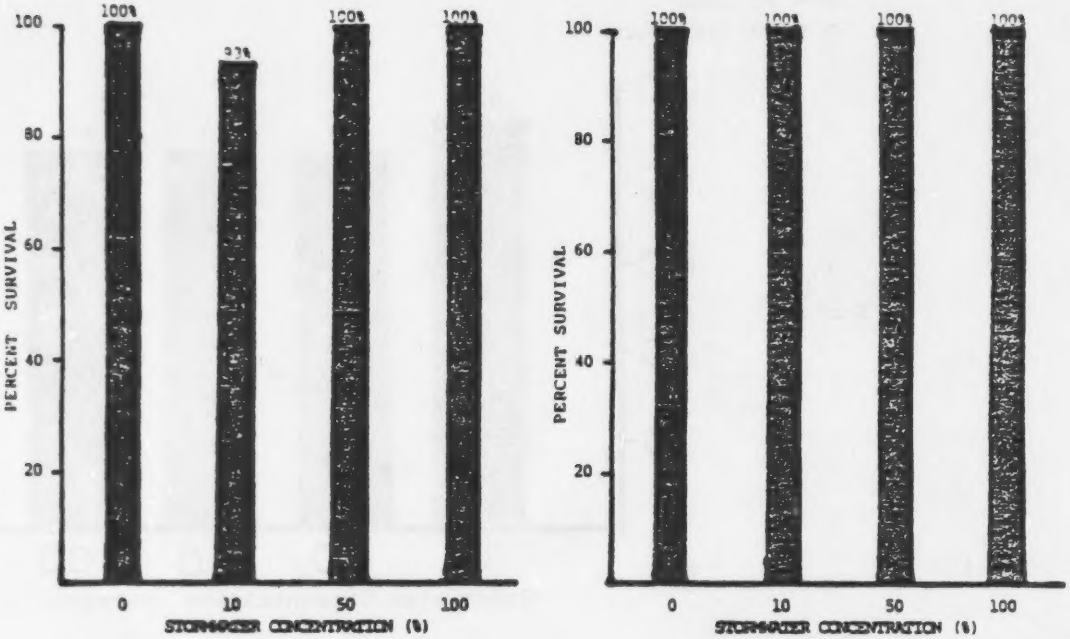
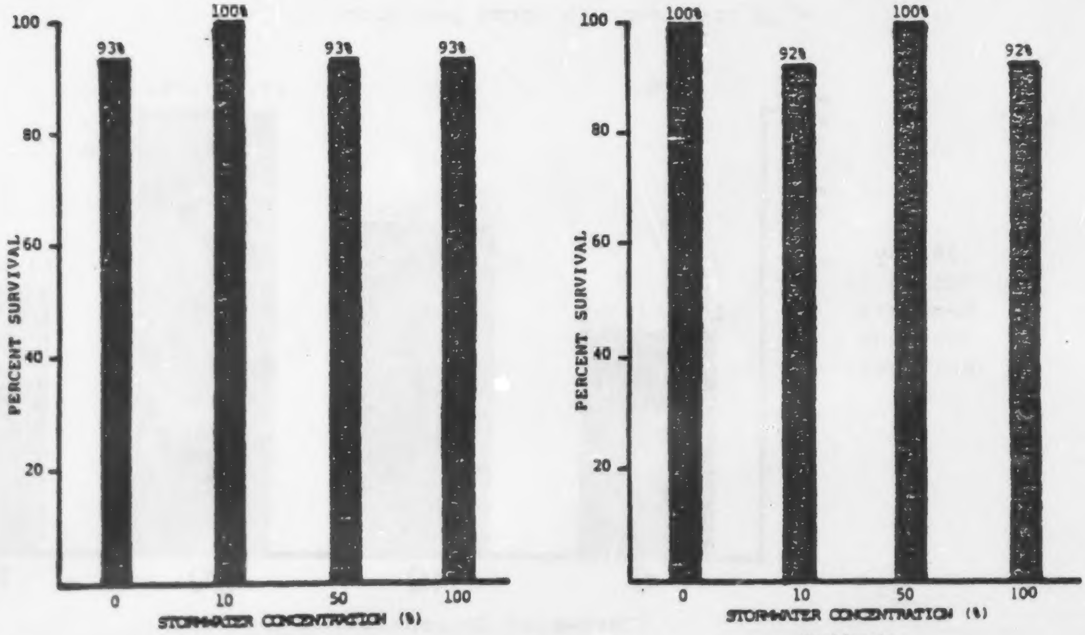
Figure 15. 96 hour survival rates for Neanthes arenaceodentata and Cyprinodon variegatus exposed to October, 1982 stormwater from Artic Street outfall, T= 24 C, S= 25‰, n= 15/ treatment



Neanthes

Cyprinodon

Figure 16. 96 hour survival rates for Neanthes arenaceodentata and Mysidopsis bahia exposed to January, 1983 stormwater from Cass Street outfall, T= 20 C, S= 25‰ n= 15 or 12/ treatment



Neanthes

Mysidopsis

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Figure 17. 28 day growth of Neanthes arenaceodentata exposed to dilutions of July stormwater.
T = 23°C
S = 25 o/oo
n = 10/treatment (one worm per dish)

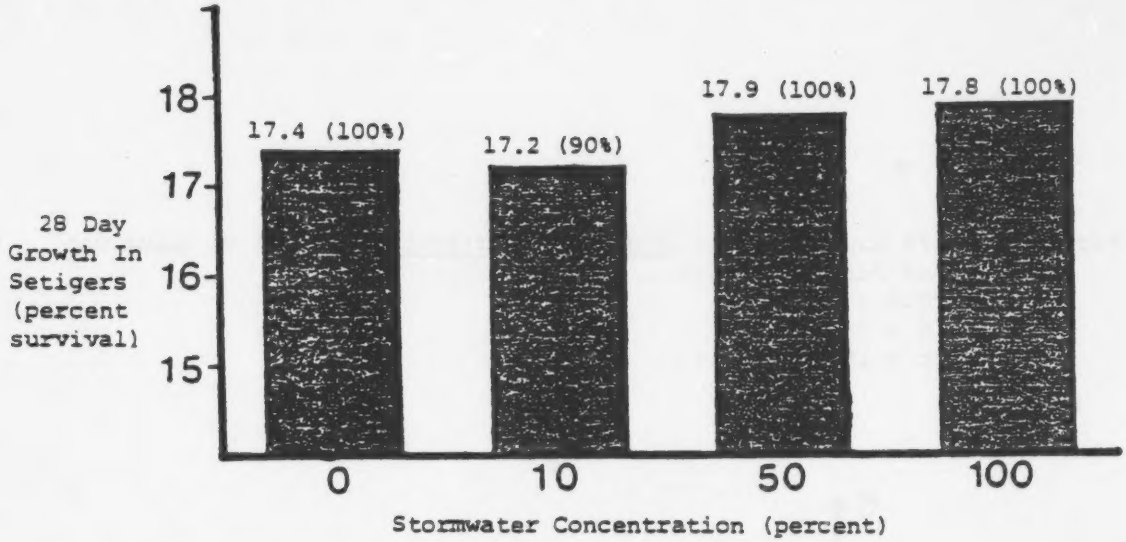
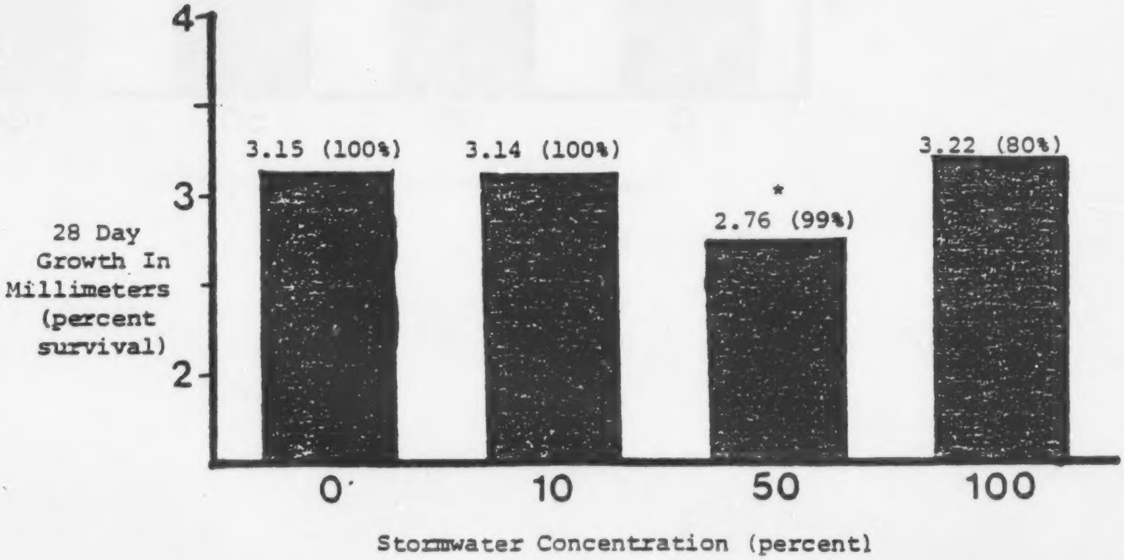


Figure 18. 28 day growth in Cyprinodon variegatus exposed to dilutions of July stormwater.
T = 24°C
S = 25 o/oo
n = 15/treatment



*Significantly different from control.

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Figure 19. 28 day growth in Cyprinodon variegatus exposed to dilutions of July stormwater.
T = 23°C
S = 25 o/oo
n = 15/treatment

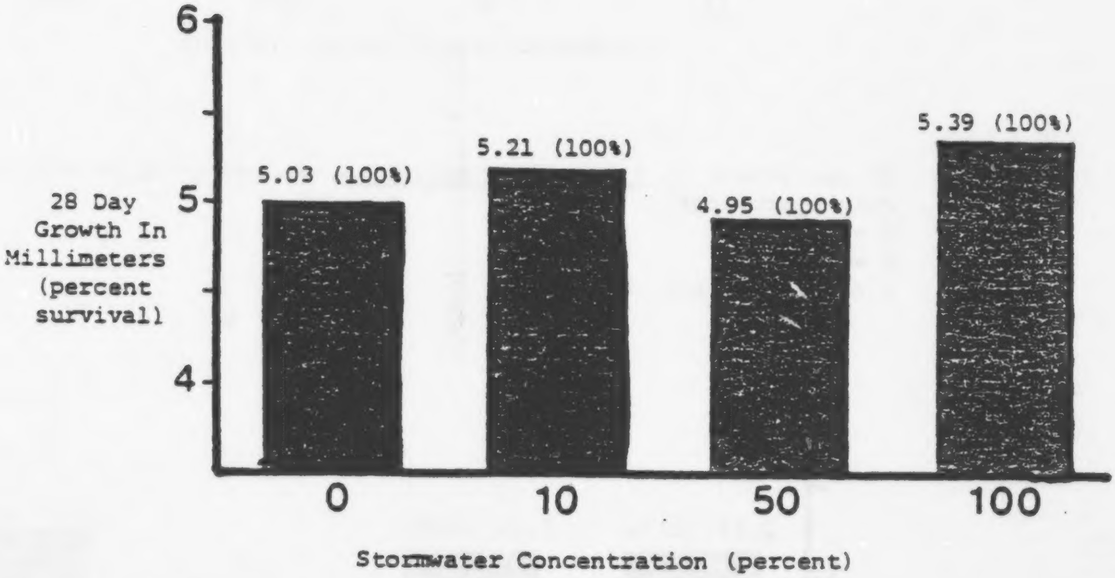


Figure 20. 96 hour survival of Neanthes arenaceodentata exposed to dilutions of July stormwtaer plus reduced salinity (30 o/oo to 15 o/oo). T = 24°C; S = 15 o/oo; n = 15/treatment

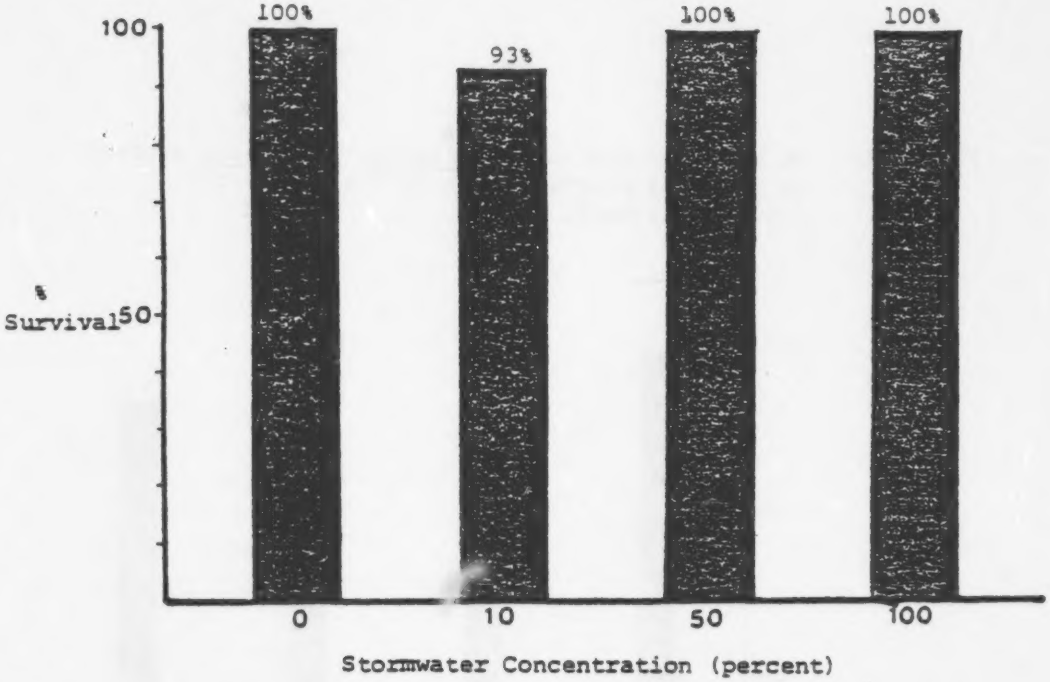
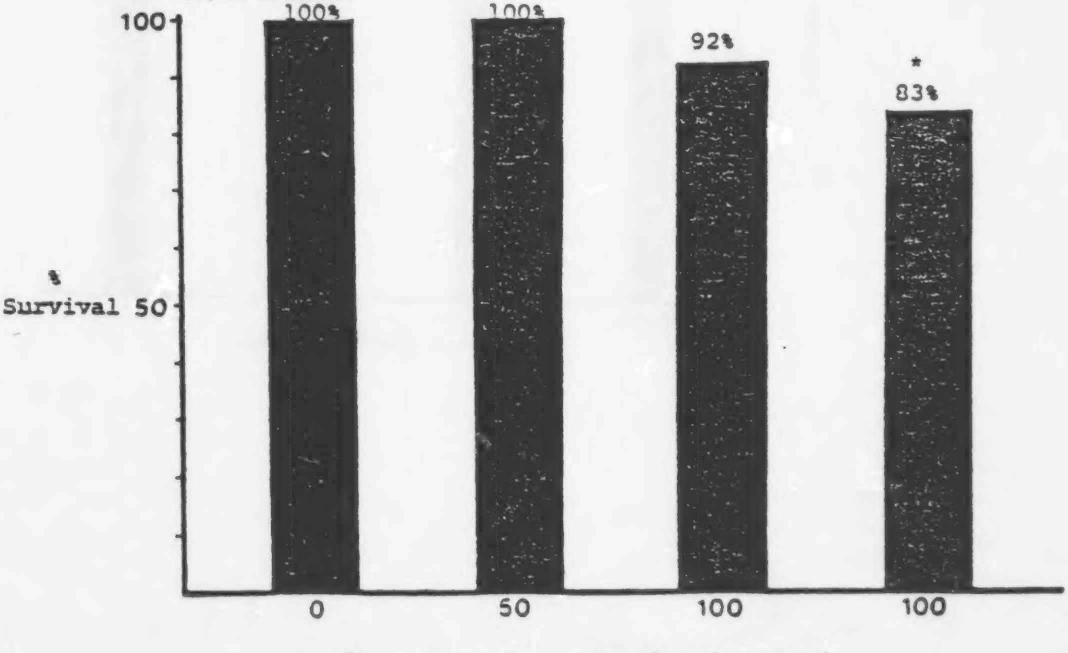


Figure 21. 96 hour and 7 day survival of Mysidopsis bahia exposed to dilutions of July stormwater plus reduced salinity (25 o/oo to 15 o/oo).
T = 23°C
S = 15 o/oo
n = 15/treatment



*This bar represents survival rate in 100% stormwater and reduced salinity after 7 days and is significantly different from controls.

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Figure 22. 96 hour survival for Cyprinodon variegatus exposed to May 1983 stormwater at 24°C and 15 o/oo, n - 15/treatment.

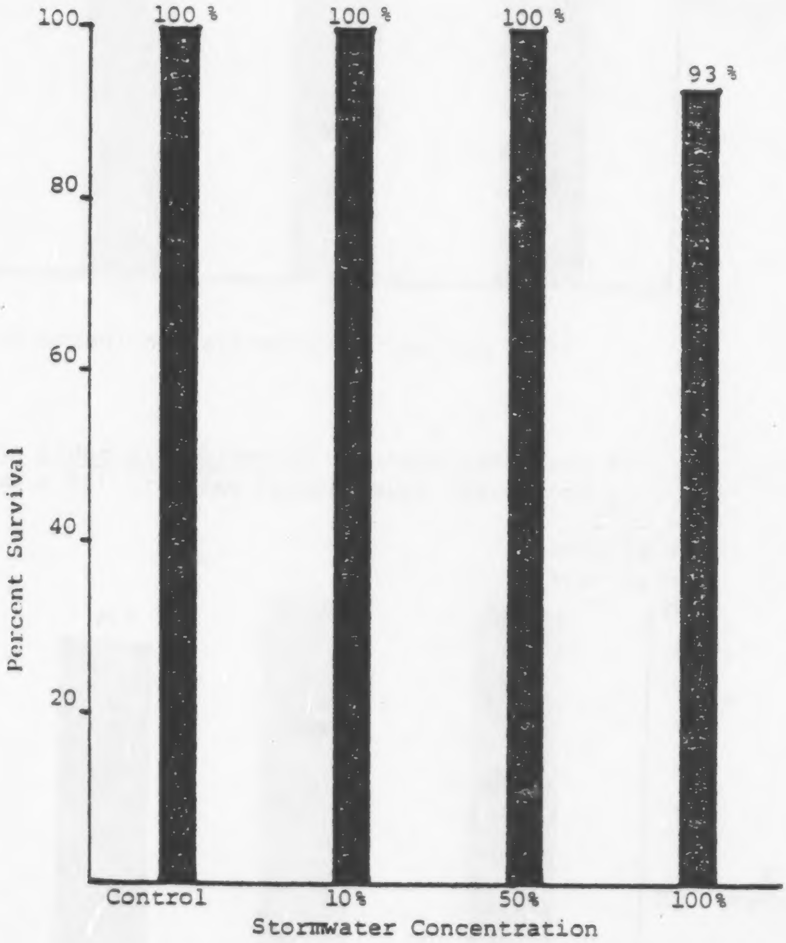


Figure 23.
96 hour survival rate for Neanthes arenaceodentata exposed to May 1983 stormwater at 24°C and 20 o/oo, n = 10/treatment.

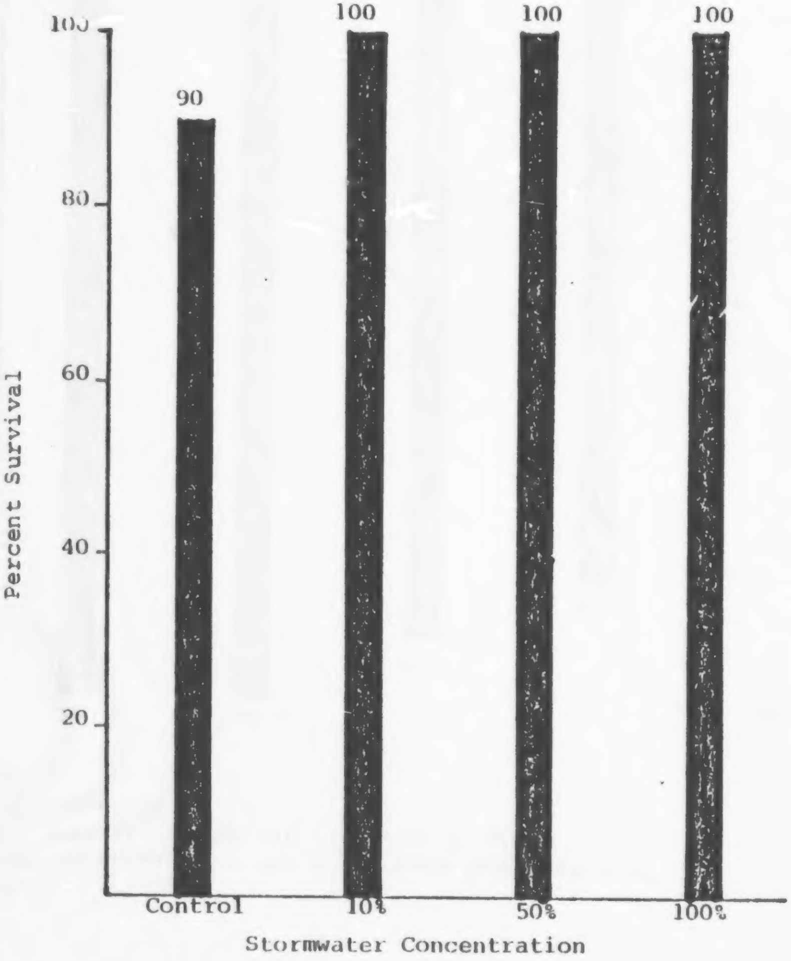
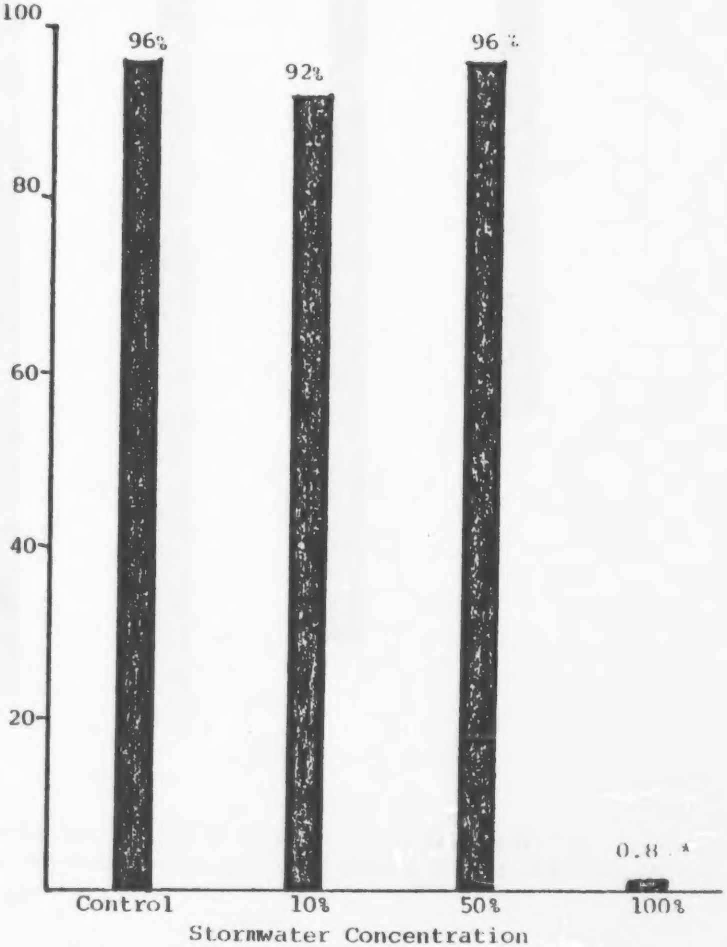


Figure 24.
96 hour survival rate for Neanthes arenaceodentata exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 25/treatment.



* significantly different from control

Figure 25.
96 hour survival rate for Mysidopsis bahia exposed to May 1983 stormwater at 24°C and 20 o/oo, n = 15/treatment.

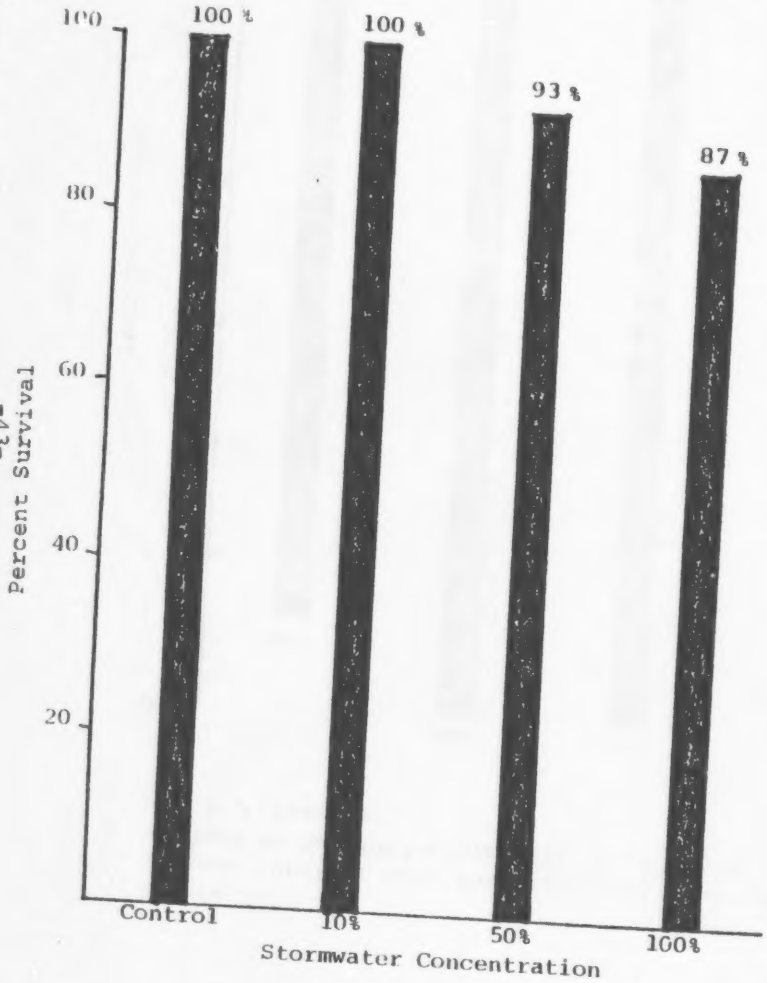


Figure 26.
96 hour survival rate for Mysidopsis bahia exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 15/treatment.

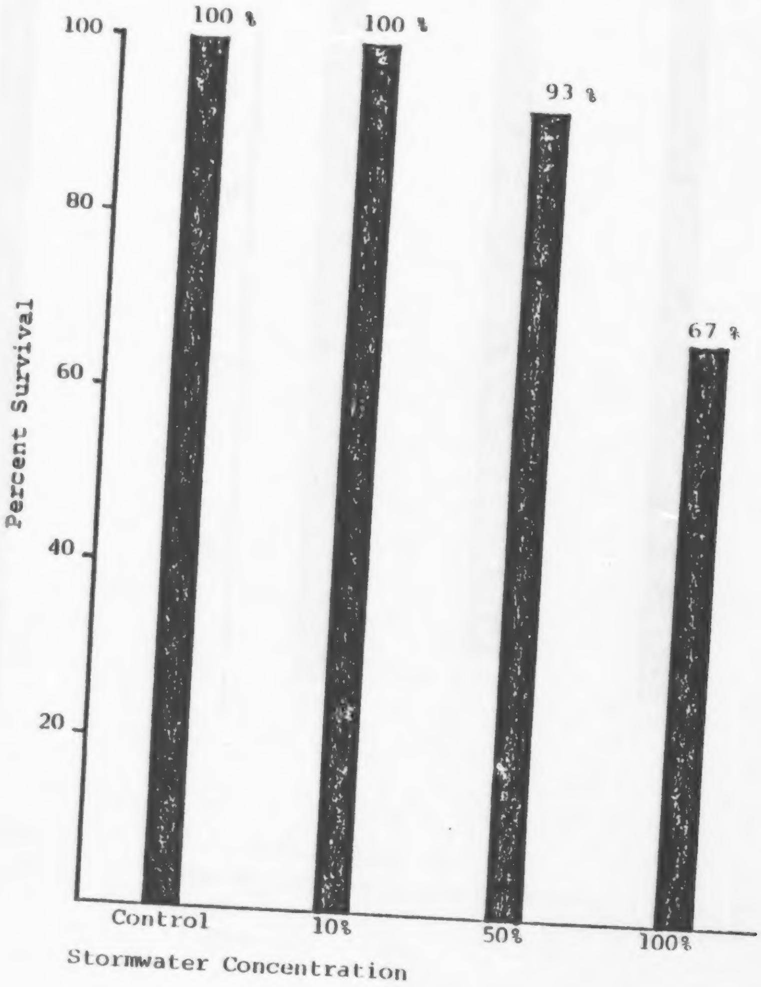


Figure 27.
96 hour survival rate for Mysidopsis bahia exposed to filtered May 1983 stormwater at 24°C and 15 o/oo, n = 15/treatment.

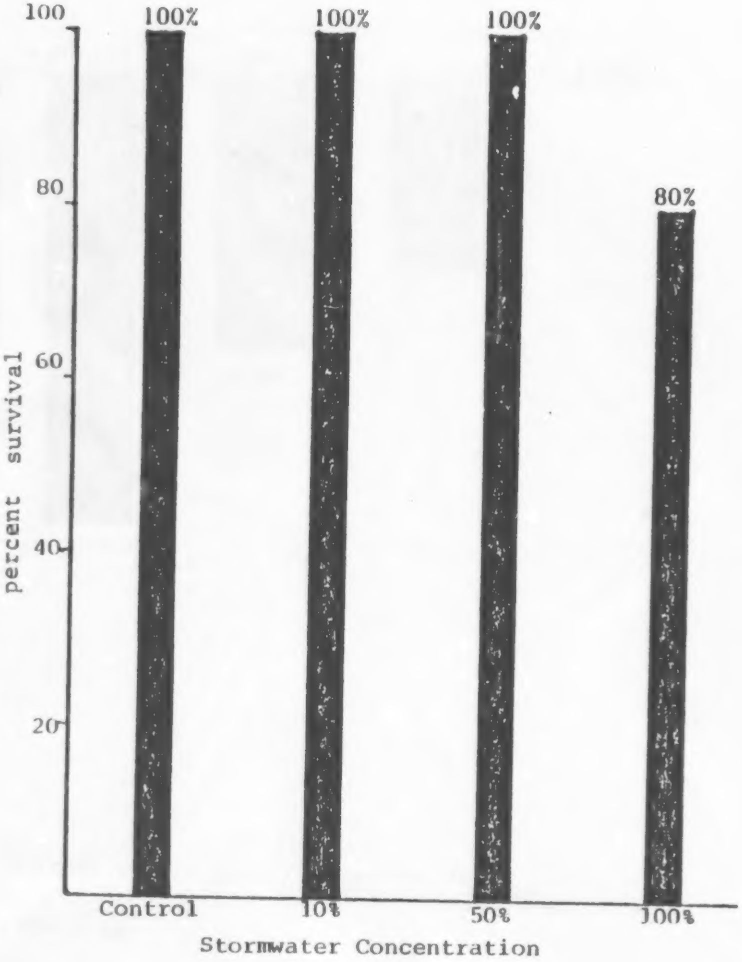
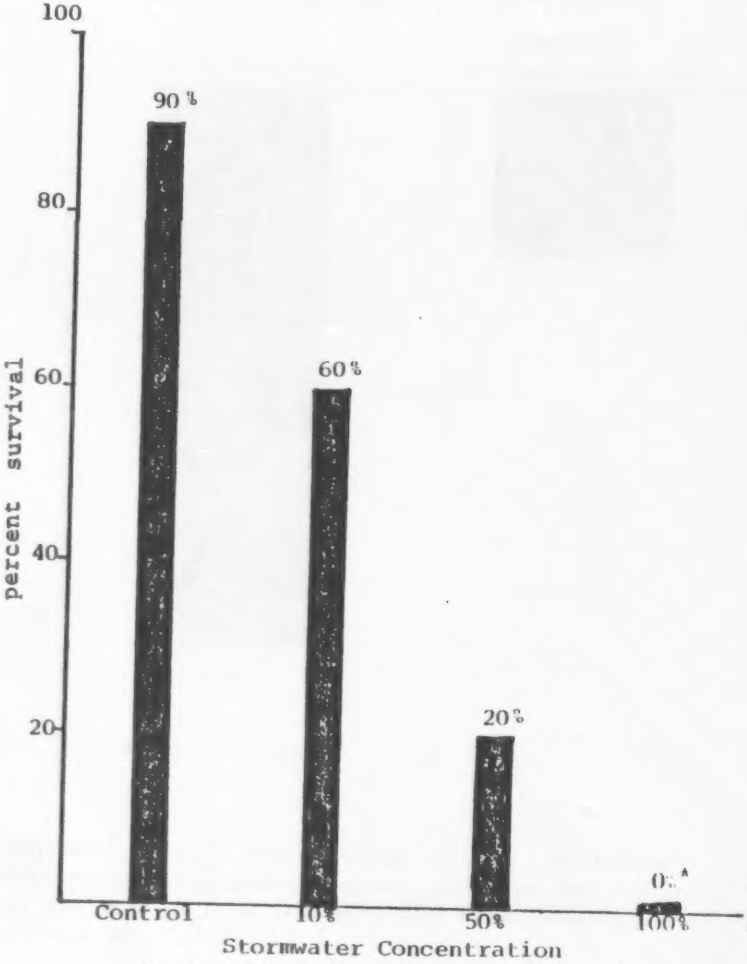
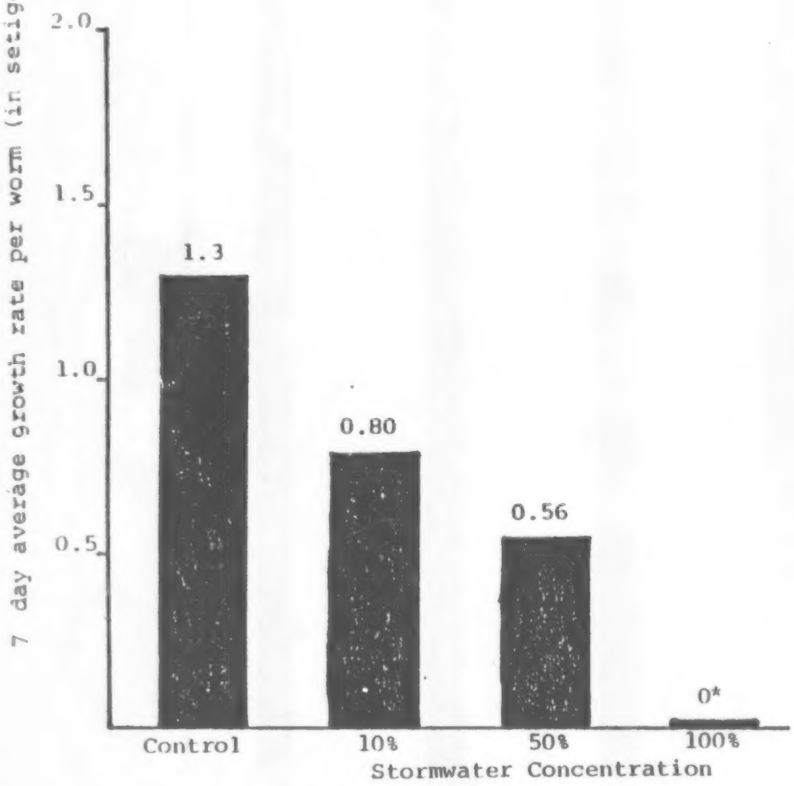


Figure 28.
96 hour survival rate for Neanthes arenaceodentata exposed to filtered May 1983 stormwater at 24°C and 15 o/oo, n = 10/treatment.



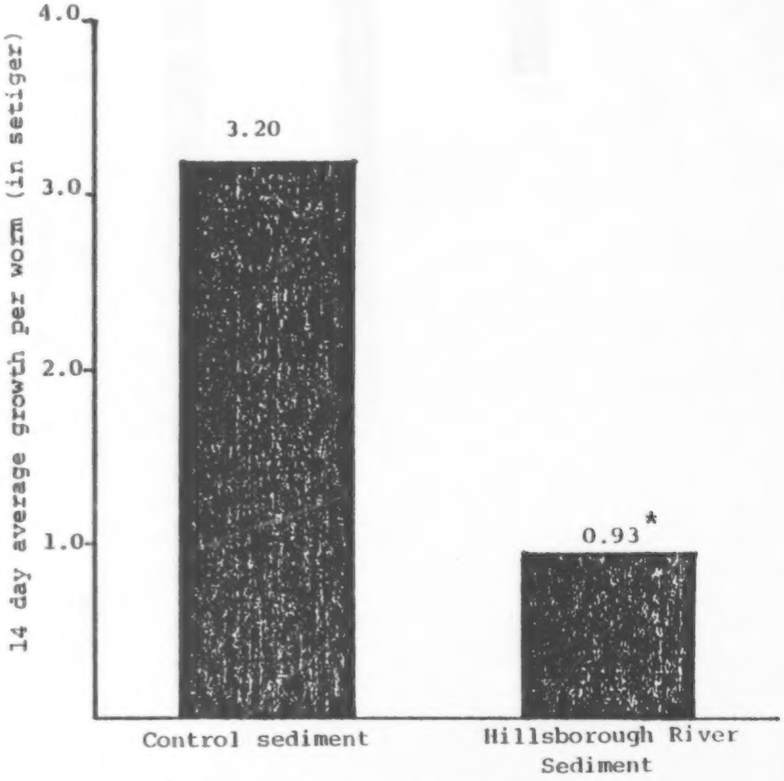
* significantly different from control

Figure 29.
7 day growth rate for Neanthes arenaceodentata exposed to May 1983 stormwater at 24°C and 15 o/oo, n = 10/treatment.



* significantly different from control

Figure 30.
14 day growth rate for Neanthes arenaceodentata exposed to Hillsborough River sediment and control sediment at 24°C and 25 o/oo, n = 25/treatment.



*significantly different from control

Sediment Bioassays

Toxicity tests with whole composite sediment from the Hillsborough River were conducted using Neanthes, Mysidopsis and Cyprinodon as test organisms. The results of these tests are presented in Tables 6, 7, and 8. For Neanthes, a 14 day exposure to test sediments resulted in a significant reduction in growth rate compared to controls (Figure 30). Mysidopsis bioassays revealed a significant reduction in survival after 96 hours exposure to test sediment. No reduction in growth rate was evident for Cyprinodon following 14 days exposure. All of the above tests were carried out at 25 o/oo salinity and a pH of 7-8.

Suspended Particulate Phase Bioassays

Each of the three primary bioassay species was exposed to four different solutions extracted from Hillsborough River sediments under various conditions of salinity and pH. The results of these suspended particulate phase (SPP) bioassays are presented in Tables 6, 7, and 8.

In tests using Neanthes (Table 6), significant reductions in survival and growth rates were apparent at low salinity (15 o/oo) and pH values of 8 and 6. Tests at higher salinities (20 o/oo) did not produce significant results.

Mysidopsis tests with the SPP are summarized in Table 7. Reduced survival rates were observed in three of the four combinations but proved to be statistically nonsignificant due to high variance between replicates.

Table 8 presents the results of SPP bioassays with Cyprinodon. No significant reductions in growth rates were observed at any of the combinations listed.

D. Conclusions

The conclusions that can be drawn from the above experiments include: 1) July 1982, October 1982 and January 1983 stormwater (all wet season) from the Artic Street drainage basin and Cass Street outfall is not acutely toxic to appropriately sensitive bioassay organisms; 2) this stormwater does not produce a significant reduction in growth rate of these organisms following 28 days exposure; 3) salinity reduction in combination with stormwater exposure does not cause a significant reduction in survival after 96 hours exposure to wet season runoff; 4) dry season stormwater from the Artic Street watershed is acutely toxic to invertebrate species tested, especially at low salinities (15 o/oo); 5) filtered dry season runoff produced a similar toxic response as unfiltered stormwater when tested at 15 o/oo salinity; 6) dry season stormwater produced a significant reduction in growth rate for *Neanthes* but not for *Cyprinodon*; 7) Hillsborough River sediments proved to be toxic to two of three species tested; and 8) solutions extracted from river sediments were toxic to some species at low salinities (15 o/oo).

The sensitivity of the three primary bioassay species cultured at MML to various heavy metals in solution is presented in Table 9. Acute sensitivities are expressed as the 96 hour LC_{50}, while chronic sensitivities refer to that concentration of heavy metal which results in a significant reduction in reproductive potential. Most of the 96 hour LC_{50} values in Table 9 were determined at MML using cultured organisms. However, some values were obtained from literature reports. The concentration of heavy metals in the stormwater samples is presented at the bottom of Table 9. The wet season stormwater heavy metal concentrations are considerably lower than the 96 hour LC_{50} values. The dry season runoff concentrations, especially the first flush sample, are considerably higher than the wet season values and exceed the 96 hour LC_{50} values for some species. The river sediment concentrations of heavy metals are extremely high and are undoubtedly responsible for the observed toxic effects. The fact that the dry season runoff and river sediments were not as toxic as might be expected from their chemical composition alone indicates that some portion of the total concentration is present in a chemical form that is not readily available (non toxic) to the test organisms. This situation has been documented with contaminated dredged material.

Table 6. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Neanthes arenaceodentata*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Growth rate & survival	14 days	Significant reduction in growth rate[2]
Composite SPP	20 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	15 o/oo pH 8	Growth rate & survival	10 days	Significant reduction in growth rate and survival
Composite SPP	20 o/oo pH 6	Growth rate & survival	10 days	No reduction in growth rate
Composite SPP	15 o/oo pH 6	Growth rate & survival	10 days	Significant reduction in growth rate and survival

---

[1] Results are presented as response of animals relative to control treatment.

[2] Significance refers to $P < 0.05$ using Students' t Test or single classification ANOVA.

Table 7. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Mysidopsis bahia*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Survival	96 hrs	Significant reduction in survival[2]
Composite SPP	20 o/oo pH 8	Survival	96 hrs	Reduced survival but NS
Composite SPP	15 o/oo pH 8	Survival	96 hrs	Reduced survival but NS
Composite SPP	20 o/oo pH 6	Survival	96 hrs	No reduction in survival
Composite SPP	15 o/oo pH 6	Survival	96 hrs	Reduced survival but NS

---

[1] Results are presented as response of animals relative to control treatment.

[2] Significance refers to $P < 0.05$ using Students' t Test or single classification ANOVA.

NS = not significant.

Table 8. Whole Sediment and Suspended Particulate Phase (SPP) Bioassays with *Cyprinodon variegatus*.

Toxicant	Test Conditions	Test Parameters	Test Duration	Results[1]
Whole sediment	25 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate[2]
Composite SPP	20 o/oo pH 8	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	20 o/oo pH 6	Growth rate & survival	14 days	No reduction in growth rate
Composite SPP	15 o/oo pH 8	Growth rate & survival	14 days	Reduced growth but NS
Composite SPP	15 o/oo pH 6	Growth rate & survival	14 days	No reduction in growth rate

---

[1] Results are presented as response of animals relative to control treatment.

[2] Significance refers to $P < 0.05$ using Students' t Test or single classification ANOVA.

NS = not significant.

Table 9. Laboratory Toxicity Values for Standard Bioassay Organisms Exposed to Heavy Metals in Solution. and Chemical Composition of Stormwater and Sediment Samples.

SPECIES		Copper µg/l	Cadmium µg/l	Lead µg/l	Mercury µg/l	Zinc µg/l
Neanthes arenaceodentata	Acute 96 hr LC_{50}	350*	3300*	7500	100	670*
	Chronic	--	1000**	3100**	--	320**
Mysidopsis bahia	Acute 96 hr LC_{50}	--	15.5***	--	--	<1000*
Cyprinodon variegatus	Acute 96 hr LC_{50}	13800*	12200*	--	--	7800*
July 1982 stormwater		40	10	280	0.75	130
October 1982 stormwater		5	2	210	--	163
January 1983 stormwater		32	1	130	--	205
May 1983 stormwater ****		38	4	500	--	530
May 1983 first flush		--	30	1600	--	970
May 1983 sediment samples (ug/kg wet wt.)		--	1000	107000	--	69000
Suspended particulate phase (20 o/oo pH 6.0)		--	10	2800	--	2065

*Determined at MML.
**From Reish, et al. 1978
***From Nimmo et al., 1977
**** average suspended particulate load, 214 mg/l

IV. ALGAL ASSAYS

A. Introduction

Urban stormwater runoff has been shown to contain nutrients which may contribute to growth of phytoplankton in receiving water bodies. In some cases, this augmented phytoplankton growth may lead to eutrophic conditions and reduced water quality. Urban runoff pollutants may inhibit phytoplankton growth if present in sufficient quantities. Typically, a balance exists between the nutritive potential and toxic potential of runoff, and this balance can be measured through algal assay experiments. The present algal assays were designed to measure the effects of Artic Street drainage basin runoff upon natural and cultured phytoplankton. Only wet season runoff was tested due to the unavailability of dry season runoff during the operational phase of the algal assay system.

B. Methods

Acid washed, 250 ml cotton stoppered flasks were filled with 112 ml of water containing natural and cultured phytoplankton species, and the experiment initiated on July 19, 1982. The experiment ran for 2 weeks, terminating 2 August 1982.

Water samples were collected on July 19 at the four sites (Station 1 = University of Tampa site; Station 2 = Sligh Avenue Bridge; Station 3 = Buffalo Avenue Bridge; Station 4 = 22nd Street Bridge) along the Hillsborough River. Water temperature ranged from 28.5°C to 32°C at the time of collection.

The natural river water was filtered (0.45 um Millipore filter) to remove all phyto- and zooplankton and a dilution series (100%; 10%; 1%; 0% runoff) was used with the Artic Street runoff collected on July 16 and held in a 4°C cold room. Added to 100 ml of the dilution series was 10 ml of unfiltered natural water from the original sites (Stations 1-4); 1 ml of a culture of *Scenedesmus quadricaudata* and 1 ml of a culture of *Anabaena flos-aquae*. All cultures were maintained on a 12 hour light/dark cycle in a growth chamber at 25°C for the two week period.

C. Results

Table 10 shows the initial (background) biomass levels of each division of natural phytoplankton populations in a sample from each station taken on July 19, 1982. The initial concentration of S. quadricaudata and A. flos-aquae were 1.99 ul/l and 0.25 ul/l, respectively, at the beginning of the experiment. All counts were carried out at 200X using an Olympus inverted light microscope.

Table 11 shows the results of 2 weeks of culture using varying amounts of runoff water and natural water with a phytoplankton supplement. In all cases, the highest total biomass counts occurred at the 10 or 100% runoff dilution levels, suggesting no toxic effects and in fact a possible addition of nutrients. However, the main contributor to the higher biomass levels was S. quadricauda and the Chlorophyceae accounted for more than 70% of all the biomass because of this. These results are presented graphically in Figure 31.

Although the data are not completely consistent, there is a trend for an increase in most classes of algae with the addition of runoff. The major exception to this can be seen for the diatoms (Bacillariophyceae).

D. Conclusions

The wet season runoff obtained from the Artic Street watershed enhanced phytoplankton growth on a short term basis. Furthermore, the green algal component, dominated by the inoculum, Scendesmus quadricauda showed growth in 100% or 0% runoff additions, while the blue-green algae, dominated by the inoculum Anabaena flos-aquae, did not. Final total cell volumes were higher than initial concentrations in all dilutions at all stations, particularly in the higher percent runoff cultures suggesting the runoff water contained nutrients and not bioavailable toxic substances. The effect of runoff in the more estuarine Stations 1 and 2 was to depress the natural populations, and only when in high enough concentration did the inocula of Anabaena and Scenedesmus show growth. Thus, freshwater addition via urban runoff may affect natural phytoplankton populations at estuarine locations in addition to stormwater borne nutrients or pollutants. The effect of dry season runoff with its generally higher pollutant loads may be different than that demonstrated for wet season runoff. Dry season

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runoff was not tested in algal bioassays due to the unavailability of runoff samples during the course of this study.

Table 10. Initial phytoplankton biomass (μl/l) at four stations.

Control	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
Station A	-	.86	.26	1.12
Station B	-	.694	.41	1.1
Station C	-	2.14	.45	2.59
Station D	-	3.27	.44	3.71

Table 11A. Biomass (μl/l) of phytoplankton at Station 1.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	2.25	24.29	2.439	28.979
10% Runoff	8.53	2.26	.253	11.043
1% Runoff	5.203	.798	.111	6.112
0% Runoff	5.03	1.75	.655	7.435

Table 11B Biomass (μl/l) of phytoplankton at Station 2.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	2.509	32.67	.145	35.324
10% Runoff	-	2.97	.374	3.344
1% Runoff	-	.886	1.949	2.835
0% Runoff	-	2.4	1.769	4.169

Table 11C. Biomass (µl/1) of phytoplankton at Station 3.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff*	-	39.55	1.56	41.11
10% Runoff⁺	-	12.9	1.13	14.03
1% Runoff⁻	-	8.69	.536	9.226
0% Runoff	-	15.64	.155	15.795

*Various diatoms present but no one species present in large numbers.

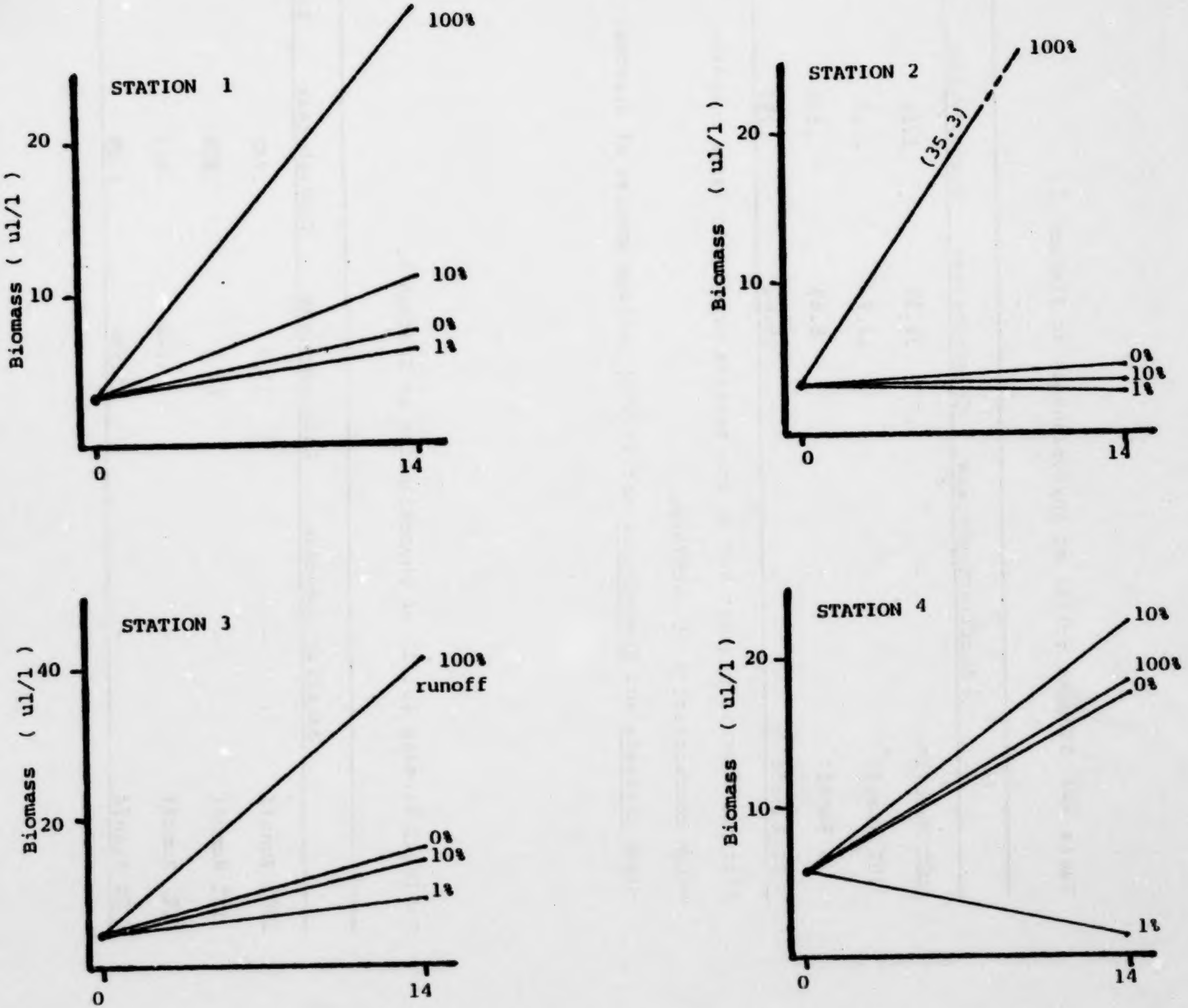
+High concentration of rotifers.

-Many Anabaena and Scenedesmus not living; various species of diatoms.

Table 11D Biomass (µl/1) of phytoplankton at Station 4.

	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Total Density
100% Runoff	-	17.7	.782	18.482
10% Runoff	-	21.5	.828	22.328
1% Runoff	-	.742	.543	1.285
0% Runoff	-	15.98	1.89	17.87

Figure 31. 14 day algal growth from laboratory experiments using river water from 4 different stations plus July, 1982 stormwater from Artic Street outfall. 100%= 100% runoff, 0% = 100% river water, etc



V. ZOOPLANKTON STUDIES

A. Introduction

Little information exists concerning the composition or dynamics of natural zooplankton populations in the Hillsborough River. The present study was undertaken to document the types and densities of zooplankton in the river and to determine how they are affected by wet and dry season conditions and by urban stormwater runoff.

B. Methods

Zooplankton were sampled at three week intervals from May 7 through August 16, 1982 at four stations on the Hillsborough River (Station 1 = University of Tampa; Station 2 = north of Buffalo Avenue; Station 3 = Sligh Avenue; and Station 4 = 22nd Street). Plankton were sampled with a high speed Miller sampler (Miller, 1961) equipped with a flowmeter and a 74 um Nitex net. An oblique tow was made at each station, beginning approximately 1 m off the bottom and ascending at a rate of 0.5 m every 30 seconds. With this procedure, each tow filtered between 600 and 2,000 liters of water (depending upon depth) and covered a distance of 75-150 m. Samples were preserved in 10% sugar-formalin solution (Haney and Hall, 1973) with rose bengal as a vital stain (Mason and Yevich, 1967).

All sampling was initiated at high tide during daylight hours. Sampling started at Station 1 and progressed upstream. The normal time interval to sample all four stations was approximately 4 hours.

On 25 August 1982, collections were made at Station 1 to assess variations in species compositions and densities over stages of a tide cycle. Sampling was initiated at low tide (1300 hr) and repeated at two hour intervals up through high tide (1900 hr).

In the laboratory, samples were diluted to a known volume and two or three replicate subsamples were counted in a modified rotary chamber (Ward, 1955). Subsample size was considered adequate when 200 individuals were counted and identified. Identification of specimens was to the lowest taxon possible.

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C. Results

Zooplankton densities and percentages of marine organisms (calculated two ways because of bias in each method) at four sampling stations on the Hillsborough River during dry and wet seasons are presented in Table 12. Mean zooplankton densities (mean of all four stations) were 6.94 times greater during the dry season than during the wet season. Large differences in densities between sampling stations were found in both seasons, but should not be considered significant because of the low numbers of samples (three in each season). A long term sampling program with frequent samples would be necessary to document between station differences. Mean percentages of marine organisms (for all sampling stations) were between 68.0 and 78.1% for the dry season. The only sampling station to show an appreciable difference was Station 4, which was dominated by freshwater organisms (Table 12). However, during the wet season populations at all stations except Station 1, were predominantly freshwater organisms; percentages ranged from 17.9 to 24.8% marine organisms at the upper three stations. The high percentage of marine organisms at Station 1 was attributable to a large population of clam veligers on August 16.

A list of invertebrate taxa collected in the zooplankton samples from four stations on the Hillsborough River during dry and wet seasons is presented in Table 13. Twenty eight taxa were collected and the following differences between seasons were noted: 1) the number of species of rotifers and cladocerans increased markedly at all stations during the wet season; 2) the presence of copepod species, copepod nauplii and clam veligers remained constant between seasons; and 3) barnacle life stages dissappeared at all sampling stations during the wet season. These data support the finding of a predominance of freshwater species during the wet season. However, it should be noted that the presence of freshwater species in a sample from the lower river does not reflect the physiological or reproductive states of the organisms. Additional studies are necessary to assess tolerances of freshwater organisms to low salinity environments.

Densities of zooplankton at Station 1 over different tide stages on August 25, 1982 are presented in Table 14. There was little variation in total densities or in composition of the zooplankton community from 1300 (low tide) to 1700 hours. Between 1700 and 1900, however, there was a four-fold increase in density. This increase was attributable to increases in densities of copepods, specifically cyclopoid copepods (Table 15). Both cyclopoid species, *Mesocyclops edax* and *Tropocyclops prasinus* are freshwater copepods. Thus, the increase at high tide was not attributable to influx from Hillsborough Bay. Instead, it either was due to inflow from upstream or to diurnal migration. *Mesocyclops edax* is known to be benthic during the daylight hours and to migrate into the water column during the late afternoon and evening hours.

Table 16 shows the densities of major groups of zooplankton at each station on each collection date.

D. Conclusions

This small set of zooplankton samples indicates that densities are high and are comprised principally of marine organisms during the dry season (before opening of the 30th Street Dam). During the wet season densities are low and are comprised principally of freshwater organisms. The differences in densities probably are attributable to water exchange rates (flushing times). During the dry season flushing time is slow and zooplankton populations can reproduce and increase in density as long as food is abundant. However, in the wet season, flushing time is more rapid, zooplankton do not appear to be able to maintain position within the river, and salinity changes may influence survival. Studies of flow rates and movements of plankton populations are necessary to confirm these hypotheses.

During the wet season, pollutant loads in the water column due to urban runoff are probably low enough to have little direct effect upon zooplankton. Flow rates and flushing times probably have more influence on zooplankton composition than runoff pollutants. Dry season runoff, with its higher pollutant loads, may have acute or chronic toxic effects on some zooplankton species especially near major storm drains. The long term effects of pollutant accumulation in river sediments on zooplankton communities remains to be determined. Zooplankton species provide a food source for pelagic species and also contain larval forms that colonize the benthos. These species represent an integral part of the river ecological system.

TABLE 12. Comparison of total densities of zooplankton at four stations on the Hillsborough River at time intervals before and after opening of the 30th Street Dam; dry versus wet seasons. Two estimates of percentage of marine organisms are presented also: the upper estimate is the percentage of total organisms captured during the sample interval, and the lower estimate is the mean of daily percentages.

Time Interval	Density in No. per Liter & Percent Marine Species at Four Sampling Stations Station 4	Station 3	Station 2	Station 1	Mean
Before					
May 7-June 15	70.39	272.83	250.97	70.95	166.28
	37.2%	96.0%	71.2%	74.5%	78.1%
	48.7%	90.5%	71.8%	61.2%	68.0%
After					
July 6-August 16	2.64	1.61	3.03	88.57	23.96
	20.6%	20.3%	24.8%	69.8%	66.2%
	20.3%	17.9%	24.8%	50.9%	28.4%
Total					
May 7-August 16	36.51	137.16	127.00	79.76	95.11
	36.6%	95.6%	70.6%	71.9%	76.6%
	34.5%	54.2%	48.3%	56.1%	48.3%

TABLE 13. List of invertebrate taxa collected in zooplankton samples from the Hillsborough River, Florida May-August 1982. Freshwater taxa are indicated with an asterisk (*), and estuarine and marine taxa with a plus (+). Presence of each taxon at each station during wet and dry seasons also is indicated.

	STATION							
	4		3		2		1	
	D	W	D	W	D	W	D	W
Phylum Rotifera								
Class Monogononta								
Family Brachionidae								
*Brachionus caudatus**								X
*Brachionus havanensis**		X		X		X		X
Brachionus plicatilis+		X					X	X
Euchlanis sp.*	X	X		X				X
*Keratella erlinae**		X		X		X		X
*Kellicottia bostoniensis**								X
Lepadella sp.*		X						
*Platyias quadridentata**		X		X		X		X
Family Lecanidae								
Lecane sp.*		X		X		X		X
*Monostyla bulla**	X	X		X		X		X
Family Asplanchnidae								
Asplanchna sp.*		X				X		
Phylum Annelida								
Class Polychaeta								
Unid. polychaete larvae+	X	X	X	X	X		X	X
Phylum Arthropoda								
Class Crustacea								
Subclass Branchiopoda								
Order Cladocera								
*Diaphanosoma leuchtenbergianum**		X		X		X		X
*Daphnia ambigua**		X				X	X	
*Simocephalus expinosus**		X			X	X	X	X
*Ceriodaphnia lacustris**	X	X	X	X				
*Leydigia quadrangularis**		X		X		X		
*Bosmina longirostris**	X	X		X	X	X	X	X
Subclass Copepoda								
Order Calanoida								
*Diaptomus dorsalis**	X	X	X			X	X	X
Paracalanus spp.+	X	X	X	X	X	X	X	X
Order Cyclopoida								
*Tropocyclops prasinus**	X	X	X	X	X	X	X	X
*Mesocyclops edax**	X	X	X	X	X	X	X	X

Order Harpacticoida								
Euterpina sp.+	X	X	X	X	X	X	X	X
Copepod nauplii*+	X	X	X	X	X	X	X	X
Subclass Cirripedia								
Unid. barnacle nauplii+	X		X		X		X	
Unid. barnacle cypris larvae+	X		X					
Subclass Malacostraca								
Order Decapoda								
Rhithropanopeus harrisii (zoea)+	X		X				X	
Phylum Mollusca								
Class Pelycopoda								
Unid. clam veliger+	X	X	X	X	X	X	X	X
TOTAL NUMBER OF TAXA	15	23	12	17	10	18	14	20

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TABLE 14. Changes in the densities of zooplankton at Station 1 at different tide stages on August 25, 1982.

		Density in Number Per Liter						
Time (hrs)	Tide Stage	Total Organisms	Cope-pods	Nauplii	Roti-fers	Clado-cera	Clam veligers	Polychaete larvae
1300	Low	2.43	0.92	1.16	0.07	0.00	0.28	0.00
1500	Low	1.90	1.06	0.56	0.03	0.11	0.14	0.00
1700	Low	2.16	0.38	0.95	0.52	0.11	0.20	0.00
1900	High	9.35	4.76	2.78	0.20	0.13	0.98	0.49

TABLE 15. Copepod densities over a tidal cycle at Station 1 on August 25, 1982.

		Density in Number Per Liter			
Time (hrs)	Tide Stage	Cyclopoida Adults	Copepodids	Calanoida	Harpacticoida
1300	Low	0.20	0.47	0.25	0.00
1500		0.81	0.25	0.00	0.00
1700		0.21	0.06	0.03	0.08
1900	High	3.21*	1.38	0.00	0.17

*60% *Mesocyclops edax* and 40% *Tropocyclops prasinus*.

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TABLE 16. Hillsborough River zooplankton data. Stations: 4 = 22nd Street; 3 = Sligh Avenue; 2 = Buffalo Avenue; 1 = University of Tampa. Others include: crab zoea, polychaete larvae, barnacle cyprids. Density = no. organisms per liter.

STATION 4; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	4.200
Cladocera	0.320
Clam veligers	0.220
Adult and copepodid copepods	24.970
Copepod nauplii	91.170
Miscellaneous organisms	0.000
Rotifers	0.000
Total organisms	120.880

STATION 4; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	5.2000
Cladocera	0.0000
Clam veligers	10.7000
Adult and copepodid copepods	38.7000
Copepod nauplii	64.2800
Miscellaneous organisms	0.2700
Rotifers	0.0000
Total organisms	74.6800

STATION 4; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	1.9700
Cladocera	0.3700
Clam veligers	2.4600
Adult and copepodid copepods	3.4400
Copepod nauplii	6.6300
Miscellaneous organisms	0.2500
Rotifers	0.4900
Total Organisms	15.6100

STATION 4; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.28000
Clam veligers	0.08000
Adult and copepodid copepods	0.31000
Copepod nauplii	0.71000
Miscellaneous organisms	0.04000
Rotifers	1.28000
Total organisms	2.69000

STATION 4; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.20000
Clam veligers	0.15000
Adult and copepodid copepods	0.58000
Copepod nauplii	0.61000
Miscellaneous organisms	0.03000
Rotifers	0.53000
Total organisms	2.11000

STATION 4; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.12000
Clam veligers	0.06000
Adult and copepodid copepods	0.57000
Copepod nauplii	1.12000
Miscellaneous organisms	0.00000
Rotifers	1.25000
Total organisms	3.11000

STATION 3; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	0.6200
Cladocera	0.0000
Clam veligers	11.5900
Adult and copepodid copepods	0.9500
Copepod nauplii	13.1200

Miscellaneous organisms	0.5000
Rotifers	0.0000
Total organisms	26.7800

STATION 3; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	29.330
Cladocera	0.000
Clam veligers	451.350
Adult and copepodid copepods	15.380
Copepod nauplii	229.770
Miscellaneous organisms	4.190
Rotifers	0.000
Total organisms	730.520

STATION 3; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.6900
Cladocera	0.5500
Clam veligers	33.2400
Adult and copepodid copepods	10.4400
Copepod nauplii	15.1100
Miscellaneous organisms	0.8200
Rotifers	0.0000
Total organisms	60.8500

STATION 3; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.06000
Clam veligers	0.07000
Adult and copepodid copepods	0.53000
Copepod nauplii	1.08000
Miscellaneous organisms	0.04000
Rotifers	0.40000
Total organisms	2.18000

STATION 3; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.000000

Cladocera	0.130000
Clam veligers	0.000000
Adult and copepodid copepods	0.260000
Copepod nauplii	0.100000
Miscellaneous organisms	0.020000
Rotifers	0.080000
Total organisms	0.580000

STATION 3; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.02000
Cladocera	0.07000
Clam veligers	0.12000
Adult and copepodid copepods	0.55000
Copepod nauplii	0.94000
Miscellaneous organisms	0.00000
Rotifers	0.37000
Total organisms	2.07000

STATION 2; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	2.960
Cladocera	0.350
Clam veligers	2.270
Adult and copepodid copepods	4.020
Copepod nauplii	181.820
Miscellaneous organisms	0.520
Rotifers	0.000
Total organisms	191.940

STATION 2; DATE: MAY 25, 1982

Organism	Density
Barnacle nauplii	0.000
Cladocera	0.000
Clam veligers	4.990
Adult and copepodid copepods	6.240
Copepod nauplii	304.340
Miscellaneous organisms	1.250
Rotifers	0.000
Total organisms	316.820

STATION 2; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.930
Cladocera	0.930
Clam veligers	150.150
Adult and copepodid copepods	45.600
Copepod nauplii	44.690
Miscellaneous organisms	1.850
Rotifers	0.000
Total organisms	244.140

STATION 2; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.04000
Clam veligers	0.28000
Adult and copepodid copepods	0.25000
Copepod nauplii	0.76000
Miscellaneous organisms	0.00000
Rotifers	0.59000
Total organisms	1.92000

STATION 2; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.25000
Clam veligers	0.06000
Adult and copepodid copepods	0.36000
Copepod nauplii	1.45000
Miscellaneous organisms	0.00000
Rotifers	0.61000
Total organisms	2.74000

STATION 2; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.00000
Cladocera	0.16000
Clam veligers	0.50000
Adult and copepodid copepods	1.02000
Copepod nauplii	2.02000

Miscellaneous organisms	0.02000
Rotifers	0.71000
Total organisms	4.42000

STATION 1; DATE: MAY 7, 1982

Organism	Density
Barnacle nauplii	2.6500
Cladocera	0.1400
Clam veligers	2.7400
Adult and copepodid copepods	5.7500
Copepod nauplii	22.9900
Miscellaneous organisms	0.1800
Rotifers	0.0000
Total organisms	34.4500

STATION 1; DATE: MAY 25, 1983

Organism	Density
Barnacle nauplii	6.230
Cladocera	0.000
Clam veligers	5.590
Adult and copepodid copepods	3.510
Copepod nauplii	120.640
Miscellaneous organisms	0.130
Rotifers	0.000
Total organisms	136.100

STATION 1; DATE: JUNE 15, 1982

Organism	Density
Barnacle nauplii	0.0000
Cladocera	0.5500
Clam veligers	7.9000
Adult and copepodid copepods	18.3300
Copepod nauplii	15.0700
Miscellaneous organisms	0.4400
Rotifers	0.0000
Total organisms	42.2900

STATION 1; DATE: JULY 6, 1982

Organism	Density
Barnacle nauplii	0.00000

Cladocera	0.06000
Clam veligers	0.59000
Adult and copepodid copepods	0.44000
Copepod nauplii	0.13000
Miscellaneous organisms	0.03000
Rotifers	0.14000
Total organisms	1.39000

STATION 1; DATE: JULY 30, 1982

Organism	Density
Barnacle nauplii	0.0000
Cladocera	0.4700
Clam veligers	5.1900
Adult and copepodid copepods	34.8100
Copepod nauplii	18.7800
Miscellaneous organisms	0.1000
Rotifers	0.3800
Total organisms	59.7300

STATION 1; DATE: AUGUST 16, 1982

Organism	Density
Barnacle nauplii	0.000
Cladocera	0.000
Clam veligers	153.180
Adult and copepodid copepods	24.140
Copepod nauplii	23.890
Miscellaneous organisms	1.040
Rotifers	2.340
Total organisms	204.600

VI. PHYTOPLANKTON STUDIES

A. Introduction

The goal of this study was to determine the dominant species present and total cell volume of phytoplankton before and after the opening of the dam on the Hillsborough River. These data were used to study the effects of runoff on the phytoplankton populations. Samplings occurred at three week intervals from May 7 through August 16, 1982 at four stations and two sites at each station.

B. Methods

The following procedures were followed:

a) All samplings were taken at high tide during daylight hours.

b) Samplings began at Station 1 and progressed upstream, normal sampling time for all four stations was 4 hours.

c) Samplings were made with a van Dorn water bottle and were taken in the first meter of water.

d) Stations were at the University of Tampa (Station 1), the Buffalo Avenue Bridge (Station 2), the Sligh Avenue Bridge (Station 3), and the 22nd Street Bridge, about 1/4 mile from the dam (Station 4).

On August 25, a tide-state variation sampling was made at Station 1 at the University of Tampa site with collections taken every 2 hours from low tide (noon) to high tide (1900 hrs).

C. Results

Total densities, density of the dominant algal group, and chlorophyll 'a' levels are given for the 8 substations in Tables 17-20, for the dates May 7 through August 16. Note that three dates precede the dam opening (May 7 and 25; June 15) and three dates follow the dam opening (July 6, 30; August 16).

It is evident that total biomass was highest at all four stations before the opening of the dam (May 7, 25; June 15). In nearly all cases biomass was highest in substations in the river center. Diatoms were the dominant group of phytoplankton found, generally accounting for over half of the total biomass. Chlorophyll 'a' levels were highest just before the dam opened and highest at the University of Tampa site. Species composition changed from freshwater forms to marine forms, progressing from

Station 4 to Station 1.

Total density, density of the dominant algal group and chlorophyll 'a' levels are given in Table 21 for Station 1 (University of Tampa site) for August 25 in which the effects of a tidal change were followed.

It is evident that diatoms dominated at low tide and green algae dominated at high tide. A confounding factor was the effect of an incoming tide on the outflow of the river. It may be that the surface phytoplankton, which were more freshwater in nature, were held back during the period of high tide causing a biomass increase. Chlorophyll 'a' levels also changed, showing an increase with the green algae.

D. Conclusions

In general, the level of cell volume was high, approaching a eutrophic lake condition before the opening of the dam and lower afterward being similar to a lake of lower trophic status. The effect of salinity is another confounding factor and the changes in species composition both due to tidal and site location make comparisons difficult.

As with zooplankton populations, phytoplankton composition and density appears to be largely affected by river flow rates, with higher densities present during low river flow periods and lower densities during high flow periods. The net effect of urban runoff is likely to be stimulatory to natural populations of phytoplankton, although this may be tempered by changes in salinity or pollutant concentrations in certain locations.

Table 17 Total densities, density of dominant algal group, and chlorophyll a level at Station 1 (University of Tampa site) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	7.67	5.78 (Diatoms)	26.7
	B	12.67	11.91 (Diatoms)	23.2
25 May	A	26.89	24.58 (Diatoms)	32.1
	B	6.20	3.88 (Diatoms)	21.4
15 June	A	17.64	10.20 (Dinoflag.)	49.0
	B	17.90	14.36 (Diatoms)	51.5
6 July	A	5.22	4.21 (Dinoflag.)	4.3
	B	1.78	1.32 (Diatoms)	4.3
30 July	A	4.85	4.65 (Diatoms)	6.5
	B	—	—	10.1
16 Aug.	A	2.45	1.20 (Dinoflag.)	12.7
	B	2.71	1.02 (Chrysophy.)	14.7

[1] Biomass expressed as ul/l.

[2] Chlorophyll a expressed as ug/l.

A Near storm drain
B Center of river

Table 18 Total densities, density of dominant algal group, and chlorophyll a levels at Station 2 (Buffalo Avenue) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	27.61	13.36 (Dinoflag.)	33.7
	B	18.24	12.85 (Dinoflag.)	—
25 May	A	6.45	2.45 (Diatoms)	26.1
	B	7.02	3.80 (Diatoms)	11.4
15 June	A	0.94	0.37 (Cryptophy.)	7.4
	B	1.10	0.64 (Cryptophy.)	7.6
6 July	A	1.24	0.84 (Cryptophy.)	50.8 (detritus)
	B	2.62	1.06 (Cryptophy.)	32.1
30 July	A	0.83	0.48 (Diatoms)	14.1
	B	3.74	2.25 (Diatoms)	17.3
16 Aug.	A	3.95	2.37 (Diatoms)	19.0
	B	2.61	1.12 (Dinoflag.)	29.7

[1] Biomass expressed as ul/l.

[2] Chlorophyll a expressed as ug/l.

A Center of river
B Near cattails on east side

Table 19 Total densities, density of dominant algal group, and chlorophyll a levels at Station [illegible] (Sligh Ave. bridge) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	14.95	8.12 (Cryptophy.)	29.9
	B	5.53	1.96 (Cryptophy.)	3.7
25 May	A	4.67	2.06 (Diatoms)	18.81
	B	15.24	12.34 (Dinoflag.)	24.73
15 June	A	0.53	0.23 (Diatoms)	20.97
	B	0.95	0.54 (Cryptophy.)	--
6 July	A	2.46	1.18 (Cryptophy.)	27.3
	B	2.83	1.25 (Dinoflag.)	28.3
30 July	A	6.77	5.73 (Diatoms)	27.3
	B	2.34	2.01 (Diatoms)	28.3
16 Aug.	A	1.02	0.37 (Dinoflag.)	19.2
	B	0.85	0.38 (Cryptophy.)	18.7

[1] Biomass expressed at ul/l.

[2] Chlorophyll a expressed at ug/l.

A Center of river
B West bank, north of bridge

Table 20 Total densities, density of dominant algal group, and chlorophyll a levels at Station 4 (22nd Street bridge, ½ mile from dam) on the Hillsborough River.

Date	Substation	Total Density[1]	Dominant Group Density[1]	Chlorophyll a[2]
7 May	A	7.78	6.90 (Chrysophy.)	17.6
	B	1.35	0.60 (Diatoms)	10.8
25 May	A	3.58	3.03 (Diatoms)	2.0
	B	0.86	0.76 (unknown)	7.4
15 June	A	2.30	1.24 (Chlorophy.)	9.9
	B	3.07	1.60 (Chlorophy.)	6.5
6 July	A	1.30	0.61 (Diatoms)	24.1
	B	3.47	3.06 (Diatoms)	15.0
30 July	A	2.54	2.36 (Diatoms)	14.8
	B	5.29	4.43 (Diatoms)	15.6
16 Aug.	A	1.04	1.45 (Diatoms)	18.7
	B	1.68	1.46 (Diatoms)	22.5

[1] Biomass expressed at ul/l.

[2] Chlorophyll a expressed at ug/l.

A Center of river
B Near east bank

Table 21 Tidal change effect on total phytoplankton density, density of dominant group of phytoplankton and chlorophyll a levels at Station 1 (Hillsborough River at University of Tampa site) on 25 August, 1982).

Time	Substation	Total Density[1]	Density of Dominant Group[1]	Chlorophyll a[2]
12:45 PM	A	3.46	1.70 (Diatoms)	10.0
	B	6.15	3.60 (Diatoms)	20.1
2:45 PM	A	2.45	1.71 (Diatoms)	22.7
	B	2.24	1.54 (Diatoms)	43.7
4:45 PM	A	2.94	1.78 (Chlorophyl.)	34.3
	B	1.14	0.33 (Cryptophy.)	33.3
6:45 PM	A	4.92	2.15 (Chlorophy.)	33.0
	B	1.93	0.82 (Dinoflag.)	25.8

[1] Biomass expressed as ul/l.

[2] Chlorophyll a levels expressed at ug/l.

A Near storm drain
B Center of river

VII. LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY

A. Introduction

This section describes the findings and recommendations from the Hillsborough River receiving waters biological study, Task V, conducted by Mote Marine Laboratory (MML) and Mangrove Systems, Inc. (MSI) for the City of Tampa. Task V has these objectives:

- o To identify existing shoreline conditions, including public shores and stormwater outfalls;
- o To identify opportunities for increasing shoreline vegetation and modifying existing stormwater outfalls on public shores for the purpose of improving water or habitat quality in the lower Hillsborough River.

Described herein are the findings on shoreline types and use, based upon two boat trips along the river shores from Davis Island to the reservoir, and two land-based tours.

B. Results

Shoreline Categories

Shorelines of the Lower Hillsborough River were classified by the structures or vegetation thereupon. Nonexclusive categories used in this study are listed below.

1. Bulkheads

A bulkhead is a wall or embankment constructed to protect the shore from erosion. Bulkheads are typically made of concrete slabs poured in place or elsewhere; or bricks, blocks, sandbags or other materials bound with a cement matrix. Bulkheads on the lower river are made of poured slabs, concrete block, sandbags, wood, or steel.

2. Riprap

Riprap is a loose assemblage of broken stones erected on shors to protect against erosion. Riprap is usually distinguished from fill by involving graded banks, roundstone or roughly uniform size, and their stable arrangement. Materials used for riprap on the lower river include stones (mostly limestones), blocks and slabs of cement, or composites.

3. Fill

Fill is earth dredged from the river or dumped onto shorelines to increase upland property or retard erosion. Occasionally, fill material will contain logs, large blocks, rubbish, or other incompatible objects. The fill may be vegetated or not.

4. Native Shores

These are banks of the river judged by their aspect, elevation, and relation to other features to be not greatly different than their historic condition. Vegetation on native shores may be residential landscape, exotic, or native. Examples of each are given below.

Residential Landscape:	Willow, hollies, palm, bamboo, fig, citrus.
Exotic Vegetation:	Australian pine, punk tree (cajeput), Brazilian pepper, *Eucalyptus*.
Native Vegetation:	Cypress, leatherfern, cattail, black needlerush, oak, palm.

5. Related Features

Observations were also made on the erosion of hardened and other shores, limits of salt and freshwater indicators, and novel uses of the river.

Shoreline Condition

1. Overview

Approximately 54 percent of the lower river shorelines have been hardened. The shores hardened by bulkhead constitute ca. 47 percent; riprap, 8 percent. About 13 percent of the river's shores are filled but unhardened and 34 percent are native. (Note: A total of 102% for these figures is due to their nonexclusive nature.) Most bulkhead was of poured slab construction (6.3 mi). Concrete block bulkhead accounted for 1.5 mi total. Wood and cemented sandbag bulkhead each totaled 0.4 mi; all but 2 segments of wood walls are of recent construction. Another half mile of bulkhead (total) is constructed of miscellaneous material. Riprap of all kinds accounted for 1.3 mi, and a total of 2.5 shoreline miles have been filled. A summary of shoreline composition for the east and west banks is presented in Tables 22 and 23.

Table 22.
LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY - EAST BANK.
Numbers represent inches of shoreline from a map of scale: 1 inch = 400 feet.

SEGMENT	SEGMENT LENGTH	BH SLAB+ CAP	BH CB+ MORTAR	BH SANDBAGS +MORTAR	BH WOOD	BH STEEL	BH OTHER	RR STONE OR SLAB	RR MIXED	RR TOTAL	FILL LARGE RUBBLE	FILL DIRT	FILL TOTAL	NATURAL SHORE VEGETATION (NATIVE)	(EXOTIC)	TOTAL NATURAL SHORE
PLATT/KENNEDY	7.0	7.0														
KENNEDY/CASS	5.5	5.5														
CASS - I-275	12.0	12.0														
I-275 - N. BOULEVARD	14.0	8.0			3.5	2.5										
N. BOULECARD - COLUMBUS	17.5	3.0	1.0					1.0	1.5			6.0		(IJ) 4.5(IT)		
COLUMBUS - TURTLE CR.	7.5	2.0	1.0					3.0			1.5	6.0		1.0(T)		
TURTLE CR - BUFFALO	25.0	5.5(3.0F)						6.0						6.0(IJ IT)		
BUFFALO - D.F.11-B	16.5	4.5(4.0F)		1.5				8.0			1.0			3.0(.5T)	1.0	
D.F.11-B - HILLSBORO	16.5	5.0						0.5						7.5(3.0T)	1.0	
HILLSBORO - HENRY	16.5	7.0(1.5F)	3.5								3.0			0.5	6.0	
HENRY - SLIGH	29.0	18.0(.5F)						3.5			2.0	3.0			3.0	
SLIGH - KIRBY	14.0	9.0(1.5F)			1.0		(4.0STONE)									1.0
KIRBY - I-75	18.5	2.5(2.0F)	1.0(F)		1.0						1.0			5(.5 E)	5.0(AP)	
I-75 - NEBRASKA	5.0		2.0(1F)	3.0												
NEBRASKA - CRENSHAW	17.5	4.0(1F)		2.5(2F)				1.0					2.0	9.0		
CRENSHAW - ROWLETTE	27.0	2.5	1.0(F)	1.0	2.0							2.5		12.5		
ROWLETTE - DAM	12.5													12.5		
	261.5	95.5	9.5	8.0	7.5	2.5		23.0	1.5		8.5	17.5	2.0	61.5	16.0	
		(36.5%)	(3.6%)	(3.0%)	(2.8%)	(0.9%)		(8.7%)	(0.5%)		(3.2%)	(6.6%)	(0.7%)	(23.5%)	(6.1%)	

TOTAL HARDENED SHORE - 57.9%

2,900 FT BULKHEAD IS FAILING
800 FT CONCRETE BLOCK WALL FAILING
100 FT ERODING

MOST TIDAL JUNCUS AND TYPHA 1,000' ABOVE N. BLVD
1ST CYPRESS TREE 1,200 FT BELOW BUFFALO

Table 23.

LOWER HILLSBOROUGH RIVER SHORELINE INVENTORY - WEST BANK.

Numbers represent inches of shoreline from a map of scale; 1 inch = 400 feet.

SEGMENT	SEGMENT LENGTH	BH SLAB+ CAP	BH CB+ MORTAR	BH SANDBAGS +MORTAR	BH WOOD	BH STEEL	BH OTHER	RR STONE OR SLAB	RR MIXED	RR TOTAL	FILL LARGE RUBBLE	FILL DIRT	FILL TOTAL	NATURAL SHORE VEGETATION (NATIVE)	NATURAL SHORE VEGETATION (EXOTIC)	TOTAL NATURAL SHORE
PLATT/KENNEDY	6.5	6.0	0.5(F)													
KENNEDY/CASS	6.5	6.5														
CASS - I-275	12.5	12.5														
I-275 - N. BOULEVARD	16.0	16.0														
N. BOULEVARD - COLUMBUS	21.0	4.0	5.0				14.0				6.5				6.5(BP)	
COLUMBUS - TURTLE CR.	7.0					1.0								6.0(2.5T)		
TURTLE CR. - BUFFALO	27.0	12.0(1.0F)	5.0		1.0	3.0		2.5							1.0(BP)	
BUFFALO - D.F.11-8	18.5	7.0												$7.5\left(\begin{smallmatrix}2.0J\\5.5T\end{smallmatrix}\right)$		
D.F.11-8 - HILLSBOROUGH	14.5	3.5												$8.0\left(\begin{smallmatrix}.5J\\7.5T\end{smallmatrix}\right)$	2.0(BP)	
HILLSBORO - HENRY	16.0				2.0							8.0(2.0E)		$4.5\left(\begin{smallmatrix}3.5T\\1.0C\end{smallmatrix}\right)$		
HENRY - SLIGH	30.0	2.5	7.5(1.0F)	1.0				3.0	2.0(1.0SB)			2.0		4.5	5.5	
SLIGH - KIRBY	14.0		2.0								1.0	11.0			11.0	
KIRBY - I-75	20.0	0.5						3.0			1.0			5.5(3T)	6.0	
I-75 - NEBRASKA	4.5							4.5			4.5					
NEBRASKA - CRENSHAW	18.0		6.0						3.0(SB)		1.0 TRASH			8.5(1.0C)		
CRENSHAW - ROWLETTE	25.0	1.0	5.0(2.0F)	0.5	1.0					1.5				15.0		
ROWLETTE - DAM	11.0												3.0 (ASPHALT)	9.0(4.0E)		
	268.0	71.5	31.0	1.5	4.0	4.0	117.0	13.0	5.0	19.5	14.0	21.0	38.0	68.5	32.0	100.5
		(26.6%)	(11.5%)	(0.5%)	(1.4%)	(1.4%)	(43.6%)	(4.8%)	(1.8%)	(7.2%)	(5.2%)	(7.8%)	(14.1%)	(25.5%)	(11.9%)	(37.5%)

TOTAL HARDENED SHORE - 50.9%
200 FT BULKHEAD IS FAILING
700 FT CONCRETE BLOCK WALL FAILING
1,200 FT ERODING SHORELINE

MOST TIDAL TYPHA 800 FT ABOVE COLUMBUS DRIVE
MOST TIDAL JUNCUS 50 FT ABOVE BUFFALO AVENUE

MOST UPLAND JUNCUS 1400 FT BELOW HILLSBOROUGH AVENUE; TYPHA TO DAM

F = failing; T = *Typha*; BP = Brazilian pepper; J = *Juncus*; C = cypress; E = eroding; SB = sandbag; 1 MILE = 5,280 FT

2. Trends Across the River

The east (and south) bank of the lower river has approximately 7 percent more hardened shores than the other bank. The east bank has more failing walls, totaling 2,900 ft of bulkhead and 800 ft of concrete block compared to 200 ft of bulkhead and 700 ft of block on the west bank. By proportion to the total length of these walls on both banks, twice as much concrete block wall is failing than slab types, illustrating the relative inadequacy of concrete block as wall material. More of the west bank is actively eroding (1,260ft compared to 100 ft on the other shore). This fact is attributed to the shorter length of protected shoreline and to the general southwesterly course of the river.

3. Trends Down River

Contrary to our expectations based upon the total bulkheading of the river in downtown Tampa, no trends in the amount or kind of hardened shores were otherwise evident when data were analyzed along the length of the river. Bulkhead, riprap, fill and native shores occur in varying proportions from N. Boulevard upstream to Rowlett Park.

4. Vegetation

Five species indicative of long term salinity regimes were encountered on the banks of the lower river.

a) Southern bald cypress	*Taxodium distichum*
b) Cattail	*Typha* sp.
c) Leatherfern	*Acrostichum danaeaefolium*
d) Black rush	*Juncus roemerianus*
e) Cordgrass	*Spartina* spp.

The species are listed in order of their approximate tolerance to saltwater, cypress being completely intolerant.

No clear pattern of zonation is evident among these plants along the length of the lower river due probably to logging, shoreline modifications, and the highly variable salinity regime of the river. For example, the most downstream cattails and rush occur together, approximately 1,000 ft above the N. Boulevard Bridge. Cattails grow on banks upriver to the dam, whereas the uppermost rushes were found 1,400 ft below Hillsborough Avenue.

Five small patches of rush were found altogether. Ten patches of cattails, some up to 1,500 linear ft in size, were also noted. Cypress were solitary and disjunct. The cypress found 1,200 ft below Buffalo Avenue were the most downriver of that form. Exotic vegetation occurs on the river banks in three types: as (i) pure stands of either pine or pepper; (ii) mixed species growing as fringes adjacent to native or ornamental vegetation; or (iii) as small isolated stands. All together, approximately 9,600 ft of river bank was vegetated by Australian pine or Brazilian pepper. Of that length, about one third occurred below the Sligh Avenue Bridge and could therefore be eligible for restoration as native estuarine shoreline.

Other Observations

1. Construction of various types was in progress or recently completed on the river, including seawall and riprap installations, creek "improvements", and sanitary sewerage (Figure 38). During the interval between trips, one stand of cattail fronting an apartment house was destroyed.

2. Public shores on the river are in varied condition but include segments worthy of immediate improvement. Examples include the irregular filling at Lowry Park (Figure 39), dumping of waste asphalt at Rowlette Park, and severe erosion at the Eddie Lopez tract.

3. Freshwater sources to the river were evident even though most were observed during the dry season. Minor springs were found on either shore of the river above Hillsborough Avenue, and all four creeks were flowing, albeit at low levels.

4. Vacating of rights-of-ways, mostly streets, ending at the river was noticed in several places (Figure 42). Continuation of this process may preclude use of these public lands for "pocket parks", stormwater basins, or habitat patches. At the very least DPW Stormwater Management Division should review all petitions to vacate for consistency with the stormwater control plan.

Recommendations

Our recommendations are predicated upon the following observations and opinions.

1. The lower Hillsborough River is generally free of point sources but affected in various ways by stormwater, tidal incursions, and reservoir discharge.

2. The salinity wedge ranges from Columbus Drive (where a natural sill occurs) at high flows to Sligh Avenue (where the river becomes incised) at low flow.

3. Sligh Avenue is also the upriver limit during low flows of the 5 o/oo isohale at the surface (e.g., intertidal) zone.

4. No clear patterns of natural salinity zonation in shoreline vegetation are present due to historical (e.g., logging, filling or other man-induced habitat changes) and natural causes (e.g., responses to damming, rising sea level, freeze effects, etc.).

5. Several benefits would result from the restoration/creation of plant communities on the shorelines of the lower river.

First, we recommend that the City of Tampa recognize the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements. This suggestion stems from the topographic and hydrographic character of the river (Figure 32) and the complexity of repair efforts of river segments above or below the described segment. Topographic character refers to the wide, level, historically inundated flood plain, while hydrographic character refers to the zone of salinity transition in surface waters and areas where shores are level enough to intercept runoff. The segment above Sligh Avenue contains shorelines in need of repair or restoration for aesthetic or structural reasons (e.g., irregular fill at Lowry Park; erosion at Eddie Lopez tract; or waste asphalt at Rowlette Park), but the segment's steep and intensively used shorelines will require more extensive planning for repair and may be more costly. Eventually all these areas should be restored.

Second, we recommend that a 3 phase plan of shoreline improvement be developed for the target segment, as follows:

a) creation/restoration of vegetated shorelines on public lands;

b) removal of exotic plant species from natural and filled shorelines;

c) replacement of riprap shorelines by native vegetation.

Each is developed in turn.

Creation/Restoration of Vegetated Shorelines on Public Lands

Emphasis in this phase should be placed on 3 elements:

o aesthetic improvement of public vistas;

o redesign of creek mouths for habitat value;

o creative use of drainage easements, rights-of-ways, and other public land.

Specific areas suggested for improvement include:

Creeks at N. Boulevard (near Circle Drive), Rome and Albany, Hillsborough Avenue (upstream, on either bank near flowing wells) (Figures 33, 34, & 35).

Vistas from N. Boulevard Bridge (shoreline along both banks above bridge), Columbus Drive Bridge (west bank up to Fremont), and Buffalo Avenue Bridge (between River Club and Park Lane extension) (Figure 2).

Removal of Exotic Plant Species from Natural and Filled Shorelines

The majority of unhardened shoreline on both banks occurs in the "estuarine" segment between N. Boulevard and Sligh Avenue. Some of these shores were created by filling but have not been stabilized. Regrading combined with exotic species control and replanting would establish useful habitat and reduce the adverse ecological impacts of exotic species, primarily the displacement of native vegetation which had greater habitat and erosion control value. Similar successful efforts have been accomplished along the Palm River (Courser and Lewis, 1980).

Enhancement of Riprap Shorelines with Native Vegetation

Riprap is an effective form of shoreline stabilization that can be used to promote the establishment or maintenance of shoreline vegetation. A program is needed to plant those riprap shorelines already of suitable design, reconfigure other, existing riprap shores, or build new ones as part of a planting program. Particular emphasis could be placed on street end drainageways, box culvert discharges, and other small scale shoreline features.

Third, we suggest that the City of Tampa involve citizens and shoreline owners in waterfront improvement in at least four ways.

- Produce and distribute a "Homeowner's Guide to Shoreline Management", comparable to that enclosed in the Appendix;
- Develop an incentive program for shoreline redevelopment along privately owned waterfront, such as tax relief; blue or green belt zoning; no-interest loans for shoreline restoration; or awards for civic improvements (Figures 41 & 43).
- Sponsor annual wildlife census projects in the lower river emphasizing avifauna and fishes.
- Coordinate city-county planning efforts closely, particularly in reference to linking actions recommended here, to the Planning Commission's "Hillsborough River Study" program (see Appendix).

Fourth, we strongly recommend that the City have a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review, or code enforcement programs. This authority is necessary as all submerged sovereignty lands are titled in the Tampa Port Authority, which has regulatory authority over uses of and activities in the river, but is not bound to consider the plans or programs of the City of Tampa with regard to drainage or shoreline management.

C. Conclusion

It is probably true that most great cities of the world are located on rivers and have made optimal public use of their waterfronts. During the expansion and development of the City of Tampa, no consistent vision has emerged for the public use and best management of the Hillsborough River. Now that Tampa is on the threshhold of becoming a city of international consequence, the chance to secure the urbanized river as a public resource may be irrevocably lost.

A unified plan for shoreline restoration and habitat creation in the Hillsborough River would, in summary,

- improve the aesthetic value of scenic vistas, resulting in favorable public attitudes toward river management;
- increase and improve habitat for wildlife, especially avifauna and fish;
- contribute to water quality enhancement at creek mouths and, to a lesser extent, throughout the lower river by assimilating nutrients and sequestering some contaminants, such as metals.

421-

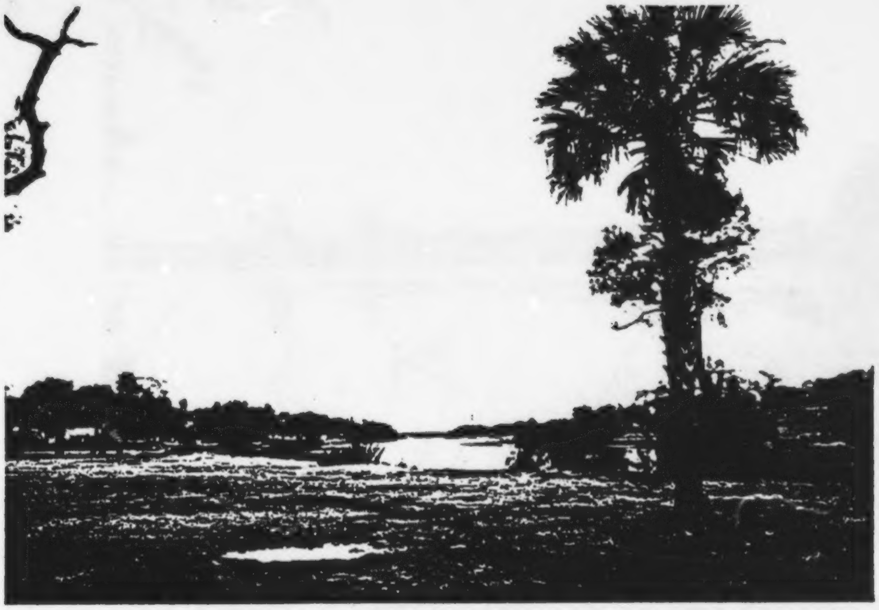

Figure 32. This photograph illustrates the low relief and wide floodplain of the Hillsborough River between Sligh Ave. and North Boulevard. This scene looks downriver from the east bank toward Buffalo Avenue. A retirement center on the west bank appears in the distance.

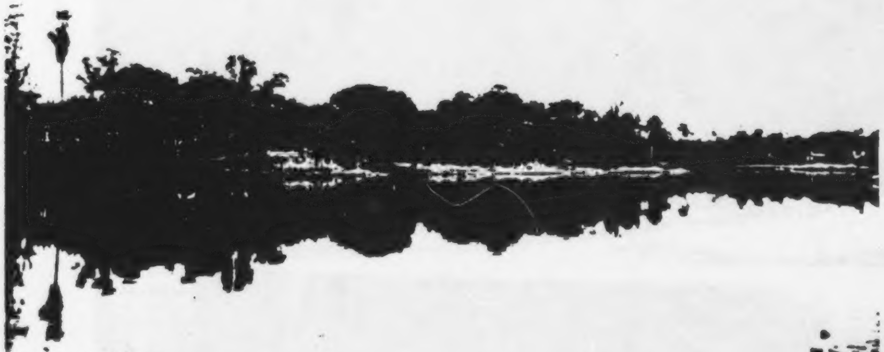

Figure 33. A scenic view from the Hillsborough Avenue bridge looking upstream to the west bank. The hammock of dense vegetation has grown around a relict spring, now capped but still flowing by seepage. Public lands between the road and river could be improved by exotic species control, regrading and planting of marsh vegetation.

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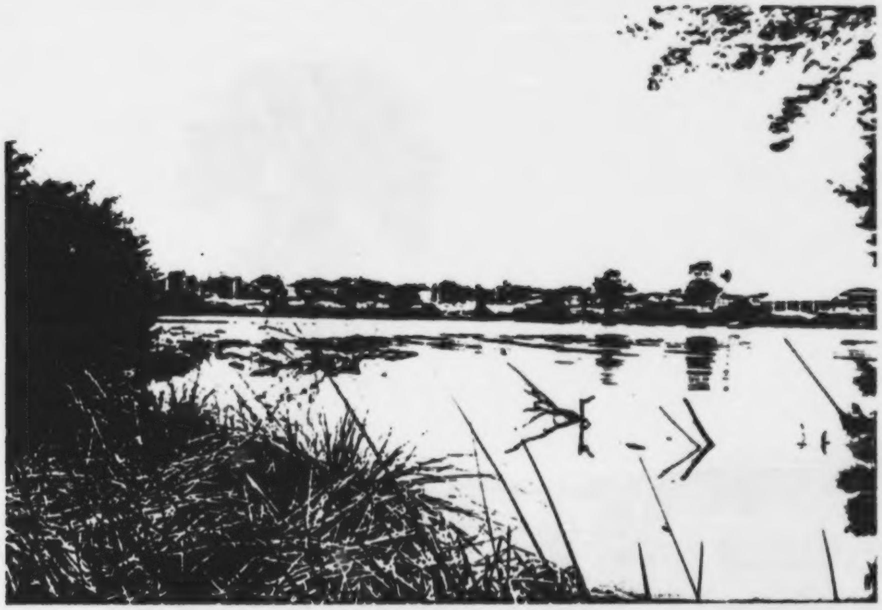

Figure 34. A creek near the North Boulevard bridge has intact banks and some native flora. Brazilian peppers are crowding the shoreline vegetation and the creekbed is strewn with debris. This creek can be improved by reshaping and planting the banks. A control placed upstream would retard discharge and scouring, and reduce sediment loading.

Figure 35. A view from across the river, looking west to the mouth of a creek near Albany and Rome. The creek proper has been encroached upon by filling but the creek mouth and river bank to the south (left in photograph) are sites worthy of study for reshaping and planting. Ideally, the creekmouth rehabilitation would be coupled with improvements upstream to the intersection of Columbus Drive and Howard Avenue.

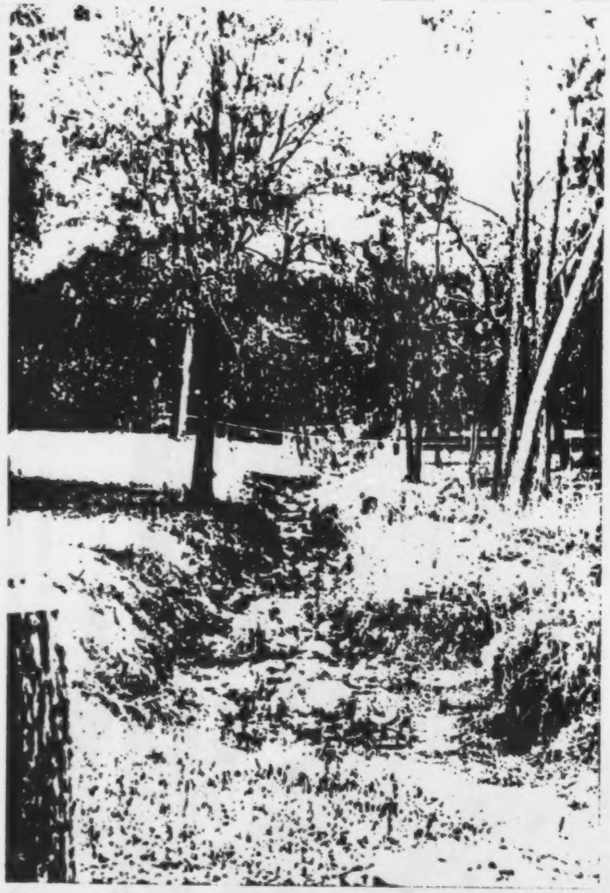

Figure 36. An example of public drainage at Ola Park. This ditch is an excellent candidate for the creation of a ponded and planted stormwater basin, as a demonstration project. Adjacent public land is ample. This shallow drainage system can be contrasted to the ravine-type gully depicted in Figure 37.

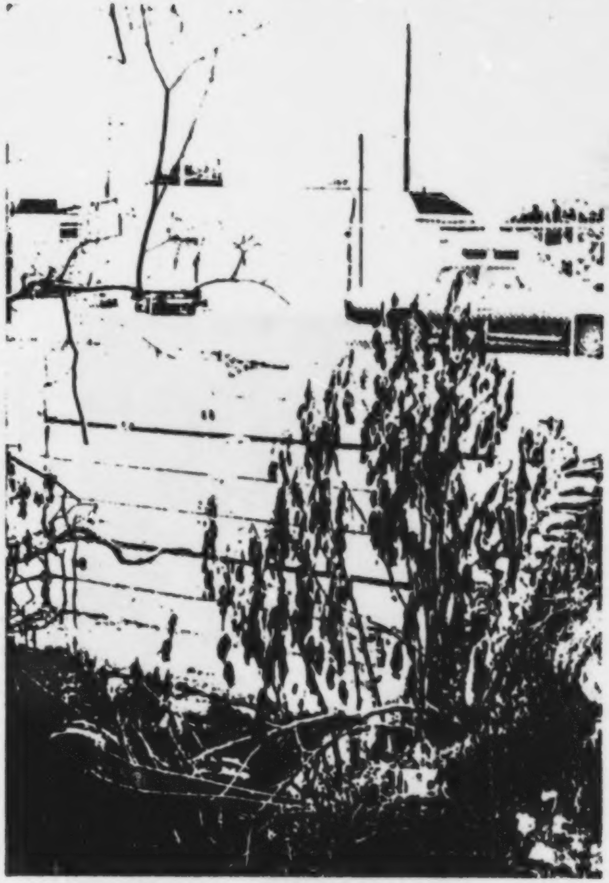

Figure 37. An example of public works "improvement". This drainageway at the northeast corner of Columbus Drive and Howard Avenue has been so enlarged that the once productive tidal creek habitat of downstream areas to the river have been destroyed, all during a period of 30 years.

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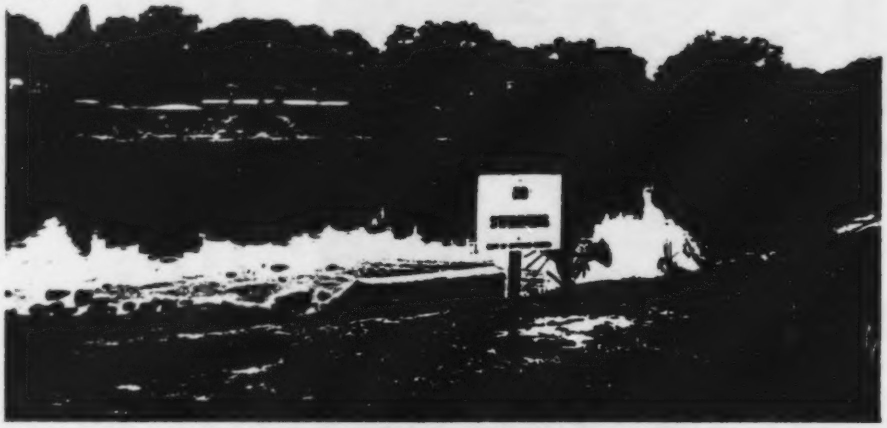

Figure 38. A sanitary sewers project conducted at this site involved crossing the river with submerged and buried pipe. The opposite shore was not graded or planted, and is presently eroding and offers negligible habitat value. Minimum standards for city, county or other public projects affecting the river and its shores could prevent such cases and contribute to water quality and habitat improvements.

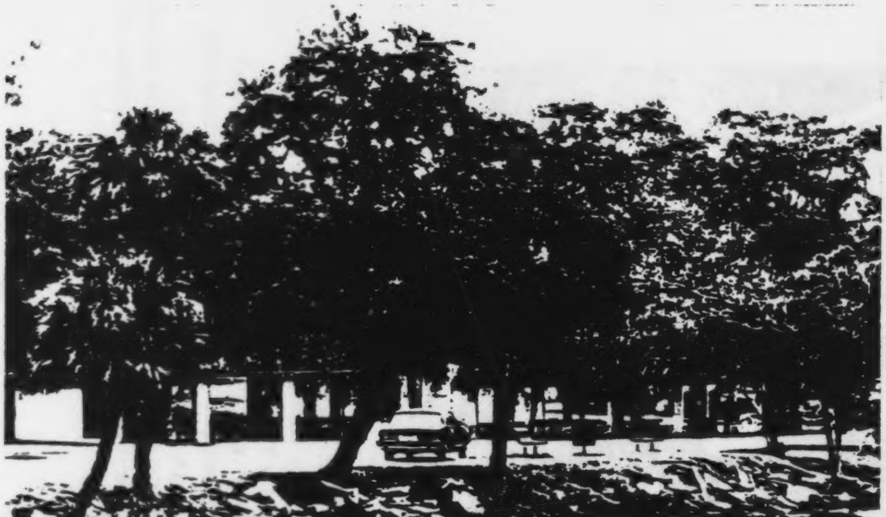

Figure 39. The west shore north of Sligh Avenue at Lowry Park is a disgrace. Piles of rubble and construction wastes have been dumped along the entire park boundary facing the river. This shoreline could be made into productive habitat and serve aesthetic and recreational needs with reshaping and planting. Minor creeks on the park could be drained through vegetated banks.

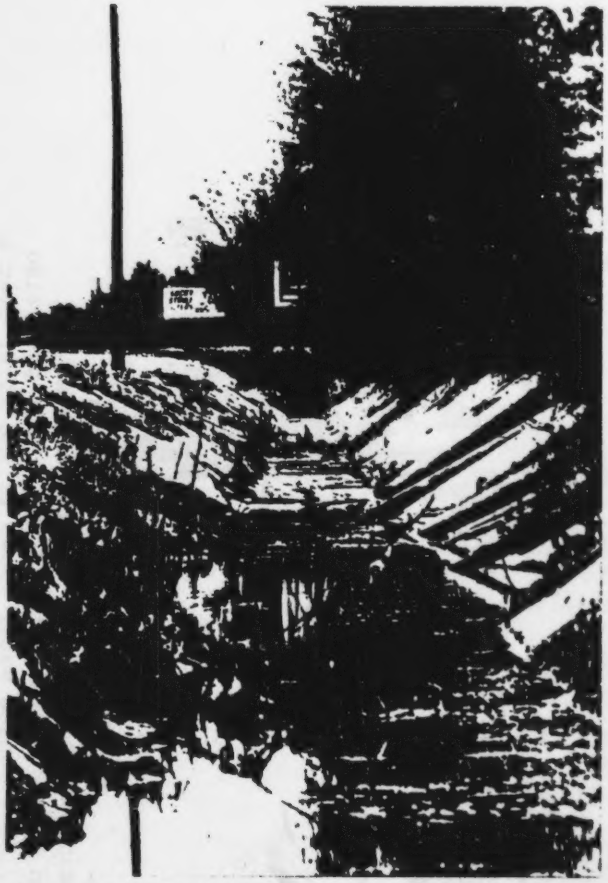

Figure 40. Storm drains leading to the river can be long, such as this one near Rowlette Park, and cover large areas where meandering, vegetated creeks could be made. Hardened ditches offer no assimilation of particulates and can worsen sediment loads where erosion occurs at failure points.

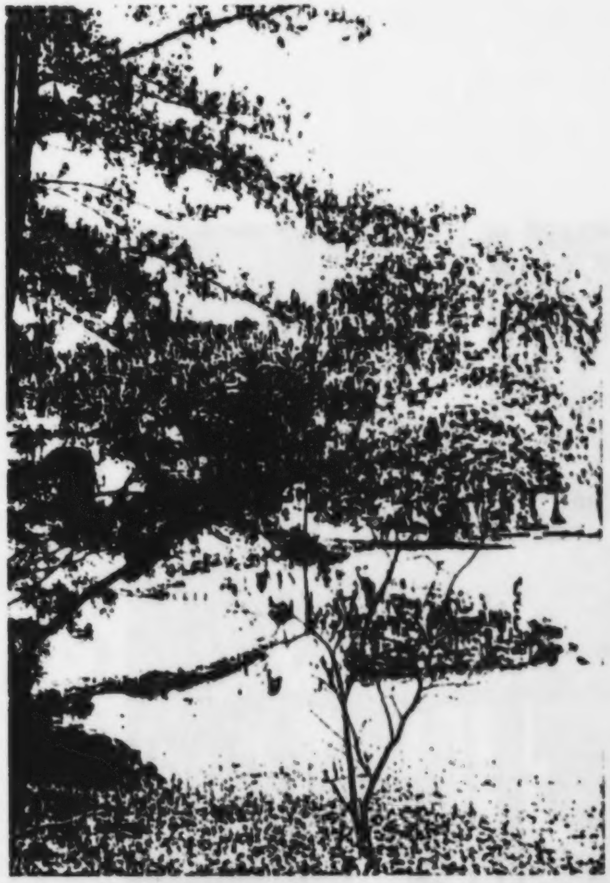

Figure 41. This photograph illustrates an example of riverfront management for stormwater. A pond once fed by artesian springs now receives direct and indirect runoff. It is controlled by a spillway near the river (behind treeline) and is attractively planted. Local residents report no odor or noxious problems.

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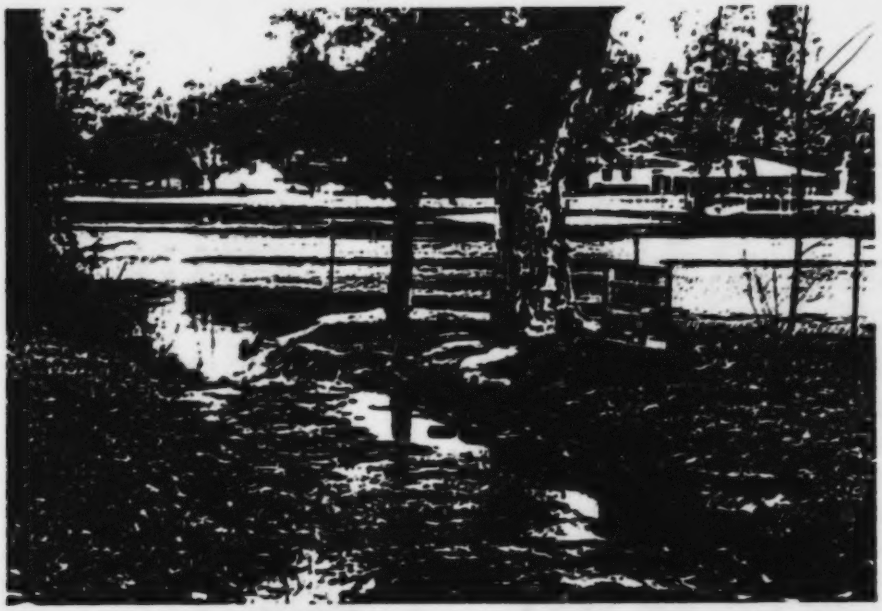


Figure 42. The end of this road abuts the river. The sign states that it may be vacated as a public way. This action will preclude using the land as a catchment for stormwater, "pocket park", or habitat patch. Note the runoff draining from the street into the river. With vacating, not only will the potential for improvement be lost, but drainage will probably be "improved" by installing a culvert.

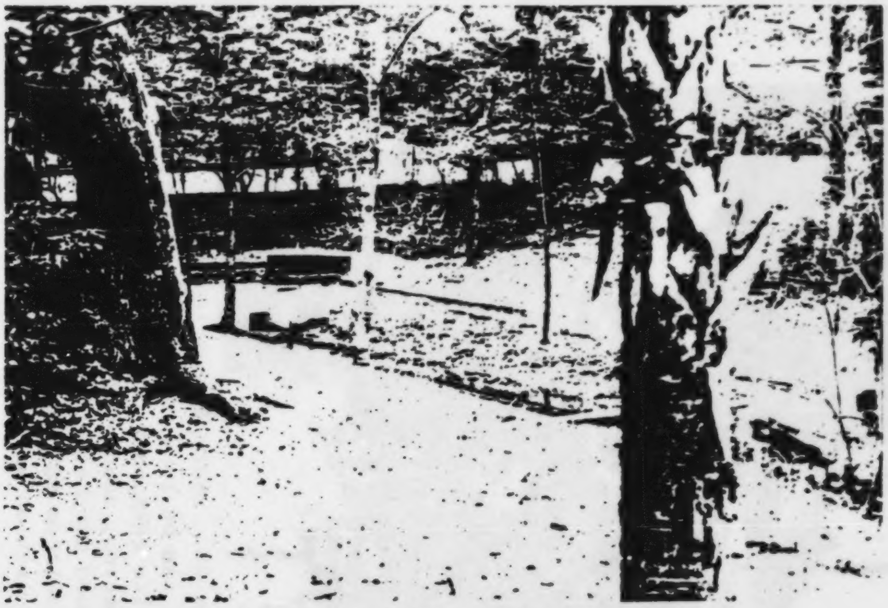


Figure 43. A private, recreational bathing area at a small springhead on the banks of the river. This pond also receives runoff. The ponded water flows to the river over a spillway. This structure is of historical interest but may also offer potential as an aesthetically acceptable catchment for sites like the one depicted in the top photograph.

VIII. HYDROCARBON STUDIES

A. Introduction

The results of the Nationwide Urban Runoff Program (NURP) studies conducted in Tampa indicate that sediment accumulation in the lower Hillsborough River represents a serious and persistent threat to water quality and the endemic biological community. Toxicity tests conducted with Hillsborough River sediments have revealed both acute and chronic toxicity of sediments to appropriately sensitive bioassay organisms. Chemical analyses of sediments have indicated high concentrations of heavy metals and petroleum hydrocarbons. Water quality studies have determined that oxygen demand in accumulated sediments can depress dissolved oxygen concentrations in overlying water.

The evidence appears conclusive that these sediments act as a sink for pollutants and for oxygen demanding material. In order to improve water quality in the river, these sediments must be successfully managed. Before this can be accomplished, the origin of the accumulated sediments needs to be determined. Potential sources of sediment include particulate matter entering the lower river via stormwater runoff, erosion of river beds and banks below the dam during periods of heavy flow and sediment transport upriver from Hillsborough Bay during tidal cycles. The relative contribution of these potential sources of sediment can be determined through detailed sediment transport studies or through the use of tracer substances carried with the particulate matter. To get an initial idea of the relative contribution of upstream and downstream transport to the sediment accumulation problem, we have used petroleum hydrocarbon analysis of sediment and suspended particulate matter as a tracer to identify the origin of accumulated sediment in the river. The specific results of this research are intended to provide the following:

a) A characteristic hydrocarbon "fingerprint" for sediments and suspended particulate matter in the Hillsborough Reservoir, lower Hillsborough River and Hillsborough Bay.

b) An analysis of the probable origin of hydrocarbons found in samples based upon previous analyses and literature reports.

c) A comparison of sample hydrocarbons with known stormwater runoff hydrocarbons as determined from previous analyses of Artic Street drainage basin runoff.

d) A comparison of hydrocarbon composition in suspended particulate matter with that of accumulated bottom sediments in the reservoir, river and bay.

e) An estimate of the relative contribution of the bay and the river to the accumulation of sediment in the river mouth based upon hydrocarbon quantity and composition in samples analyzed.

f) An estimate of the spatial influence of the bay upon the lower river based upon hydrocarbon tracers determined to originate from the bay and move upstream with tidal currents.

The rationale for this type of approach is that most petroleum hydrocarbons in freshwater or saltwater are found in association with particulate matter as adsorbed complexes. The types of petroleum hydrocarbons present in urban runoff are suspected to be different from those present in Hillsborough Bay. Therefore, qualitative and quantitative analysis of hydrocarbons will reveal the source of the pollutants as well as the source of the particulate matter since the hydrocarbons are adsorbed onto the particles.

B. Methods

Sediment samples were collected from eight sampling stations located in the Hillsborough River, three in Hillsborough Bay, and one in the Hillsborough Reservoir above the dam (Figure 5). Five of the river stations, two of the bay stations and the reservoir station were also sampled for suspended particulate matter.

1. Field Sampling

Suspended particulates were collected with water samples in 3.8 liter glass bottles. The bottles were sealed with teflon-lined caps and stored on ice for transport to the laboratory.

Sediment was collected from the upper 5 cm (surface sediment) with a petite Ponar sampler to provide information relative to recent petroleum input. A composite of three samples was collected at each site, transferred to clean glass jars and stored on ice for transport to the laboratory.

Stormwater runoff was collected during a rain event from the Artic Street basin watershed. A sample of the first flush (the first gallon of runoff) was collected along with a composite sample consisting of aliquots (1 gal. each) collected throughout the total event. The samples were placed in precleaned plastic jugs and were kept at 4°C until analyzed.

2. Laboratory Analysis

a) Preparation-Extraction

1. Sediment

Sediment subsamples from each site were thawed and thoroughly mixed in a clean glass tray. Excess water was evaporated at room temperature and the composite sample homogenized again by mixing. Aliquots of wet sediment were collected randomly throughout the sample to provide approximately 25-35 grams (g) wet weight. The sediment was placed in a Soxhlet extraction apparatus with internal standard hydrocarbons added (5-α -androstane for the aliphatic hydrocarbon fraction, and o-terphenyl for the aromatic fraction). An aliquot of methyl stearate was also added to verify complete saponification.

Extraction and saponification were performed simultaneously by Soxhlet extraction using a benzene/KOH-methanol solvent system according to the procedures of Pierce et al. (1983); Boehm (1981); and Farrington and Tripp (1975). The extracts were washed with 1% aqueous NaCl solution and the lipid material recovered in the benzene layer. Benzene was replaced with hexane as the solvent and the hydrocarbons recovered as the saturated (f_1) fraction and unsaturated (f_2) fraction by elution through a column of silica gel and alumina. Sulfur was removed by passing the eluants through copper filings.

2. Suspended Particulates

Particulate matter was collected from 1 liter of seawater sample by filtration through a Gelman A/E glass fiber filter with a nominal pore size of 0.3 um. Each filter pad was then placed in a micro-soxhlet extraction apparatus and processed as described above for sediment samples.

3. Stormwater Runoff

All samples were brought to room temperature and were mixed thoroughly to ensure homogeneity. One liter of sample was transferred to a 2 liter separatory funnel and the pH of the sample was adjusted to 1 with concentrated HCl. The sample was then extracted 3X with 50 ml of dichloromethane (CH_2Cl_2) each time. The addition of 20% sodium chloride solution and centrifugation was utilized when emulsions occurred. The combined CH_2Cl_2 extract was reduced using a flash rotary evaporatory and the CH_2Cl_2 was gradually replaced by the addition of hexane. The sample was separated into f_1 and f_2 fractions as described for sediment samples.

b) Hydrocarbon Analysis

All samples were analyzed in duplicate to verify analytical precision and sample homogenity. Reagent blanks and standard hydrocarbon samples were run with each sample set for quality assurance.

Gas chromatographic (GC) analysis of each column chromatography elution fraction was carried out with a Varian Vista 6000 gas chromatography system coupled with a Vista 401 chromatography data system. The instrument is equipped with dual flame ionization detectors (FID) and linear temperature programming. The column used was a 30 m x 0.25 mm I.D. glass capillary coated with SE-30 (Supelco, Inc.). The system was operated in the splitless injection mode for low concentrations. The carrier gas was N_2 with N_2 make up gas at the detector. Data are reported as hard copy chromatograms with qualitative and quantitative printout as well as storage on floppy discs. The 401 data system was interfaced with an Apple II Plus computer with dual disc drive for further manipulation and storage of data. The instrument was temperature programmed to recover n-alkanes from $n\text{-}C_{12}$ through $n\text{-}C_{32}$. The column is capable of resolving $n\text{-}C_{17}$ from pristane and the FID sensitivity is in the range of 1×10^{-10} g/sec (approximately 1 to 10 ng/g sample).

3. Data Analysis - Interpretation

The detection of hydrocarbons in the marine environment is complicated by the fact that the analyst must distinguish among recently biosynthesized (biogenic) hydrocarbons, hydrocarbons from fossil fuel combustion and forest fires (pyrogenic) and petroleum (petrogenic) hydrocarbons. The type of petroleum also must be discernible to ascertain the pollution source.

Much consideration has been given to the development of classification schemes to aid in hydrocarbon source identification. The basis for the most widely accepted identification scheme is separation of the hydrocarbons into aliphatic (saturated) and aromatic/olefinic (unsaturated) fractions. Analysis of these fractions by capillary GC-FID and gas chromatography-mass spectroscopy (GS-MS) provides the qualitative and quantitative information necessary to establish source classification criteria (Farrington and Meyers, 1975; Boehm and Fiest, 1980; Boehm et al., 1981; Pierce et al., 1981).

A major distinction between biogenic and petrogenic hydrocarbons is that biogenic hydrocarbons exhibit discrete sets of n-alkanes and alkenes, whereas petroleum contains the homologous series of n-alkanes, branched and cyclic alkanes and substituted polynuclear aromatic hydrocarbons. A predominance of specific compounds such as pristane (2, 6, 10, 14-tetramethylpentadecane), pentadecane (n-C_{15}), and heptadecane (n-C_{17}) are indicative of marine biogenic sources, while pristane in the presence of the isoprenoid, phytane and a homologous series of n-alkanes, indicates petroleum hydrocarbons (Ehrhardt and Blumer, 1972; Blumer et al., 1971; Farrington, 1980). Hydrocarbons of terrigenous flora exhibit a high odd/even carbon preference index (CPI) in the n-C_{23} through n-C_{31} n-alkane region (Boehm and Quinn, 1978; Farrington and Tripp, 1977; Bieri et al., 1978; Atlas et al., 1981).

Petrogenic hydrocarbons are characterized by an unresolved complex mixture (UCM) of hydrocarbons in the aliphatic fraction, which is comprised primarily of branched and cyclic saturated hydrocarbons too numerous to be resolved by gas chromatographic techniques.

Petroleum that has been recently introduced into the marine environment is indicated by a smooth alkane distribution (CPI = 1) over an UCM (Pierce et al., 1975; Farrington, 1980). Crude oil GC patterns are characteristic of geographical origin, but generally exhibit a wide boiling range of n-alkanes and UCM, sometimes with a bimodal UCM distribution. Refined petroleum distillates favor low boiling components, whereas residual oils show a predominance of the higher boiling compounds (Butler et al., 1973; Thompson and Eglinton, 1978; Traxler and Pierce, 1974).

Our approach to hydrocarbon data analysis and interpretation is to provide a GC-FID "fingerprint" chromatogram for the f_1 (saturated) and f_2 (unsaturated) fractions of each sample. Armed with this information, we can analyze trends in hydrocarbon quality and quantity from the bay to the dam for surface sediments and suspended particulate matter. Comparisons of upstream stations and bay stations with river mouth stations may indicate the source of hydrocarbons and sediments which have accumulated near the mouth of the river.

C. Results

The hydrocarbon content of stormwater runoff (July 1982 and May 1983) and Hillsborough River sediment (May 1983) was dominated by petroleum indicative of crankcase oil-like material. A summary of key parameters for hydrocarbon characterization for Hillsborough River sediment and stormwater runoff collected in May 1983 is given in Table 24. To enhance interpretation of sample hydrocarbon content from high resolution gas chromatographic (GC) analysis, chromatograms from representative petroleum contaminants (Kuwait crude oil, crankcase oil, #2 fuel oil) are given in Figure 44. Key parameters for hydrocarbon characterization of Kuwait crude oil are listed in Table 25.

It was observed that the first flush of stormwater has approximately 3 times the hydrocarbon content as that of the composite sample. This is consistent with other studies (Hoffman et al., 1982; Hunter et al., 1979) which observed higher concentrations of suspended solids, with adsorbed hydrocarbons, associated with the first flush. It should be noted that the hydrocarbon content of the stormwater runoff is probably lower than might normally be expected. This is because the initial collection procedure (sample storage in plastic jugs) was not designed for hydrocarbon analysis. Laboratory experiments have shown that hydrocarbons adsorb to plastics, effectively reducing the observed concentration in the contained water samples. Representative chromatograms from the analysis of hydrocarbons in stormwater samples are shown in Figure 45. The GC traces of the stormwater samples are similar to that of crankcase oil (Figure 44)

Table 24. Hydrocarbon Characterization of Hillsborough River Sediment and Stormwater (Artic St.) Runoff Collected May 1983.

SAMPLE	TOTAL (μg/g)		RATIOS[1]				KEY HYDROCARBONS (ng/g)[2]				N-ALKANES	
	f_1	f_2	Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	1500	1700	2085	2900	Homol. Ser.	CPI
					SEDIMENT							
Buffalo Ave.	258.96	N.C.[3]	0.06	0.80	1.38	0.38	135.49	202.65	193.64	--[4]	C_{17-26}	1.92
I-275	535.54	N.C.	0.03	0.85	0.81	0.87	145.15	146.88	324.30	--	C_{17-24}	1.28
Sligh Ave.	297.17	N.C.	0.07	0.79	1.42	0.90	159.95	183.72	154.86	3469.18	C_{17-30}	1.84
					STORMWATER RUNOFF							
1st Flush	1947.2[5]	N.C.	0.10	--	--	--	--	--	--	31.0[3]	--	--
	2127.0	N.C.	0.10	--	--	--	--	--	--	31.4	--	--
1-Hour Composite	605.2	N.C.	0.03	--	--	--	--	--	--	3.7	--	--
	631.1	N.C.	0.02	--	--	--	--	--	--	5.3	--	--
July 1982 composite	607.5	N.C.	0.07	0.60	1.19	0.74	--	250.0	--	1520.0	--	--

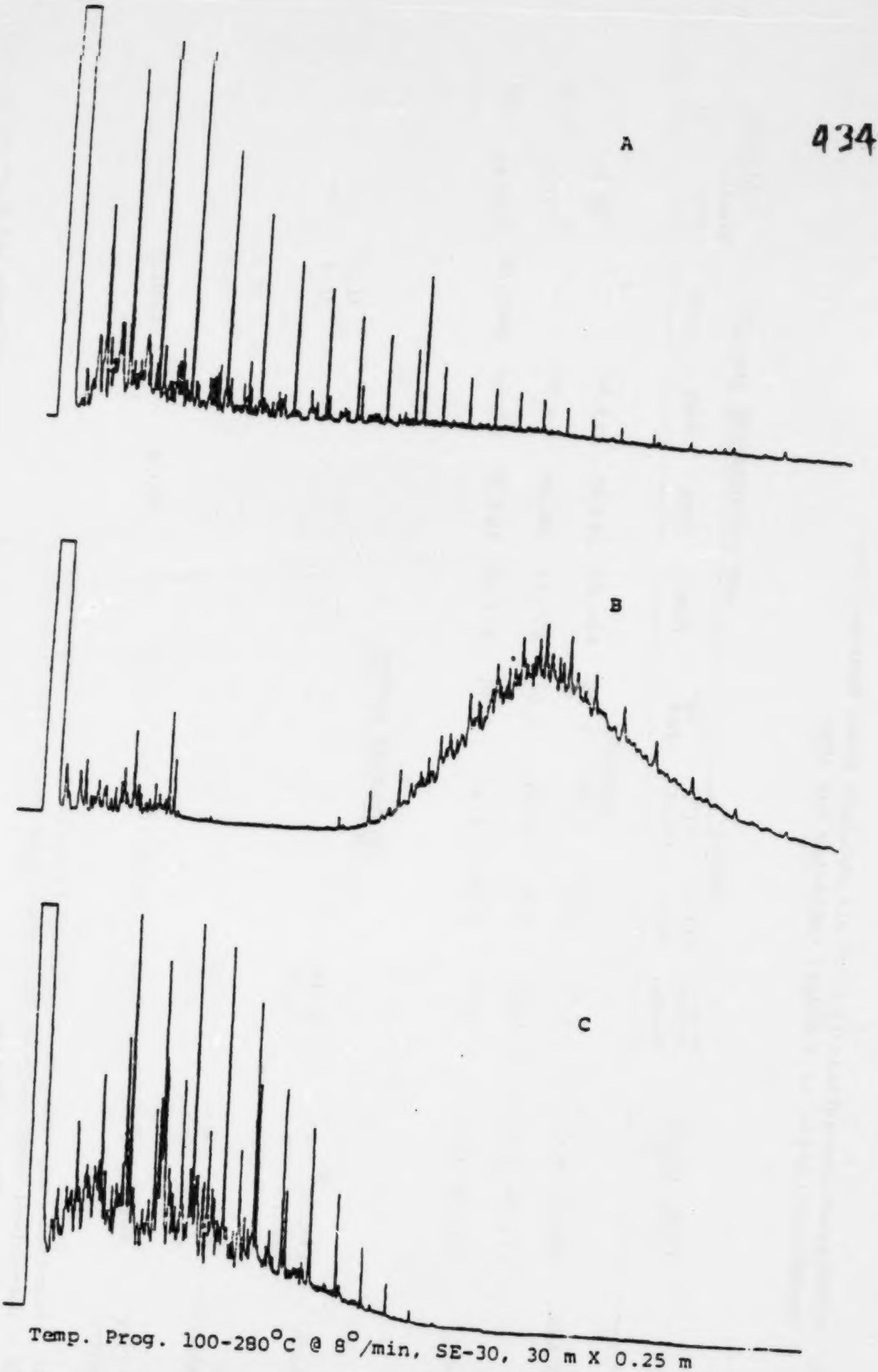
[1] Resol = Resolved components as determined from the GC-FID fingerprint
Unres = Unresolved components as determined from the GC-FID fingerprint
Prist = Pristane; Phyt = Phytane

[2] Expressed as Kovats Indices where 1500 represents n-C_{15}, 1700 represents n-C_{17}, etc. (Kovats and Keulemans, 1964).

[3] N.C. = not calculated.

[4] Not identified.

[5] μg/l.



Temp. Prog. 100-280°C @ 8°/min, SE-30, 30 m X 0.25 m

Figure 44. Reference Petroleum Contaminants: A, Kuwait crude oil; B, crankcase oil; C, #2 fuel oil.

Table 25. Hydrocarbon Characterization: Kuwait Crude Reference Oil and Recovery From Triplicate Spiked Water Samples (10 ℓ each A, B, & C).

SAMPLE	TOTAL (μg/g)		RATIOS[1]				KEY HYDROCARBONS (μg/g)[2]				N-ALKANES	
	f_1	f_2	Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	1500	1700	2085	2900	Homol. Ser.	CPI
Kuwait Crude	2294.7	N.C.[3]	0.4	0.6	5.6	3.0	51.8	36.6	--	--	C_{13-24}	0.9
A	2702.1	N.C.	0.4	0.7	4.9	2.9	64.5	50.3	--	--	C_{13-24}	1.1
B	3089.0	N.C.	0.3	0.7	4.8	2.9	55.4	46.3	--	--	C_{13-24}	1.0
C	2678.5	N.C.	0.3	0.7	5.0	2.8	54.8	44.7	--	--	C_{13-24}	1.1
$\bar{x}$	2823.2		0.3	0.7	4.9	2.9	58.2	47.1				1.1
±S	± 230.5		±0.05	±0.0	±0.1	±0.06	± 2.9	± 2.9				±0.06

[1] See Table 24.
[2] See Table 24; [3] Not calculated
[4] Mean and standard deviation of triplicate extractions (A, B, & C).

analyzed in this laboratory and others (Hoffman et al., 1982). The "fingerprint" pattern of crankcase oil and of the runoff consists of a large UCM with the boiling range from ca. n-C_{16-32} along with very few resolved components. This similar "fingerprint" pattern was also observed in Hillsborough River sediment collected May 1983 (Figure 46). It should be noted that representative chromatograms are shown to illustrate similarity in hydrocarbon patterns and are not quantitative. All hydrocarbon concentrations are calculated with respect to internal standards added prior to sample processing. Key parameters for hydrocarbon characterization of Hillsborough River sediment collected near Buffalo Avenue, I-275 overpass, and Sligh Avenue are given in Table 24. The hydrocarbon content of the sediment consisted primarily of crankcase oil-like material. Characteristic biogenic hydrocarbons were also observed, but these were less abundant than the petroleum component.

A broader study was carried out in December 1983 to more accurately characterize the hydrocarbons associated with suspended particulated matter and sediments from Hillsborough Reservoir, Hillsborough River and Hillsborough Bay. The hydrocarbon content of sediment collected throughout the entire study area (Figure 25) was dominated by petroleum indicative of crankcase oil-like material. The characteristic biogenic hydrocarbons were again observed, especially farther upriver and in the reservoir, but were less abundant than the petroleum component. Representative chromatograms from the analysis of hydrocarbons in sediment sample from the reservoir, river and bay are shown in Figure 47a-f. A summary of key parameters for hydrocarbon characterization for all sediment samples is given in Table 26. These results show an increase of sediment petroleum content going from the reservoir (Station 4-2: 25 ug/g) at the uppermost region of the study area downriver to a maximum at Station 1-2 (485 ug/g), near the I-275 bridge. The concentration then diminished on to the mouth of the river and out into Hillsborough Bay (Station 0-1: 76 ug/g). This is consistent with the hydrocarbon concentrations observed in the sediments collected in May 1983 with the highest concentration reported near the I-275 overpass (535 ug/g).

Water samples were collected simultaneously with sediment samples. No petroleum contamination was observed in any of the samples, as indicated by the representative chromatogram of the water sample along with the chromatogram of a procedural blank (Figure 48).

The hydrocarbon content of sediment collected throughout the entire study area and from stormwater runoff collected from the Artic Street watershed was dominated by petroleum indicative of crankcase oil-like material. Characteristic biogenic hydrocarbons were also observed in the sediments, but these were less abundant than the petroleum component.

The reason for a buildup of petrogenic hydrocarbons in sediment near I-275 could be a combination of several factors including: 1) chronic influx from commercial marine activities along this section of the river; 2) high loadings of petroleum contaminated stormwater from intensive use automobile traffic areas; 3) specific hydrology and sedimentology characteristics of the river at this point. Adequate interpretation of this phenomenon requires a more intensive investigation providing additional samples over time and space within this area.

The fact that the type of petroleum found in sediment (crankcase oil) very closely resembles that found in stormwater runoff strongly implicates stormwater runoff as the primary source for sediment contamination. This is supported by the observation that the hydrocarbon content of stormwater particulate matter was about ten times greater than that in sediment, indicating dilution of stormwater particulates with non-contaminated sediment and degradation-weathering of the oil after sedimentation.

Water samples (December, 1983) were collected simultaneously with sediment samples. Near surface and near bottom water was collected on the rising tide to observe the presence of petroleum contaminated particulate transport moving upriver from resuspended bay sediment. These water samples were collected during a dry period when no storm runoff was entering the river to observe petroleum input from non-storm related sources. No petroleum contamination was observed in the surface (freshwater) or in the bottom (saltwater) samples.

D. Conclusions

a) A characteristic hydrocarbon "fingerprint" for sediments and particulate matter in the Hillsborough Reservoir, lower Hillsborough River and Hillsborough Bay was provided.

b) An analysis of the probable origin of hydrocarbons found in samples indicated that crankcase-like oil was a primary contributor to sediment hydrocarbon contamination.

c) A comparison of sample hydrocarbons with known stormwater runoff hydrocarbons as determined from previous analyses of Artic Street drainage basin runoff showed that the major source of crankcase-like petrochemicals found in sediment was the stormwater runoff.

d) A comparison of hydrocarbon composition in suspended particulate matter with that of accumulated bottom sediments in the reservoir, river and bay, during a non-storm period and rising tide, indicated that most contaminated sediment transport was downriver. No upriver transport of resuspended bay sediment was observed. Additional studies should be performed over various tidal cycles and storm events.

e) An estimate of the relative contribution of the bay and the river to the accumulation of sediment in the river mouth, based on hydrocarbon quantity and composition indicates that most of the hydrocarbon contaminated sediment originated upstream.

f) No special influence of the bay upon the lower river was observed relative to hydrocarbon tracers. Additional investigations are required incorporating sediment cores, sediment grain size analysis and hydrocarbon characterization at more closely spaced stations near the river mouth to adequately evaluate this problem.

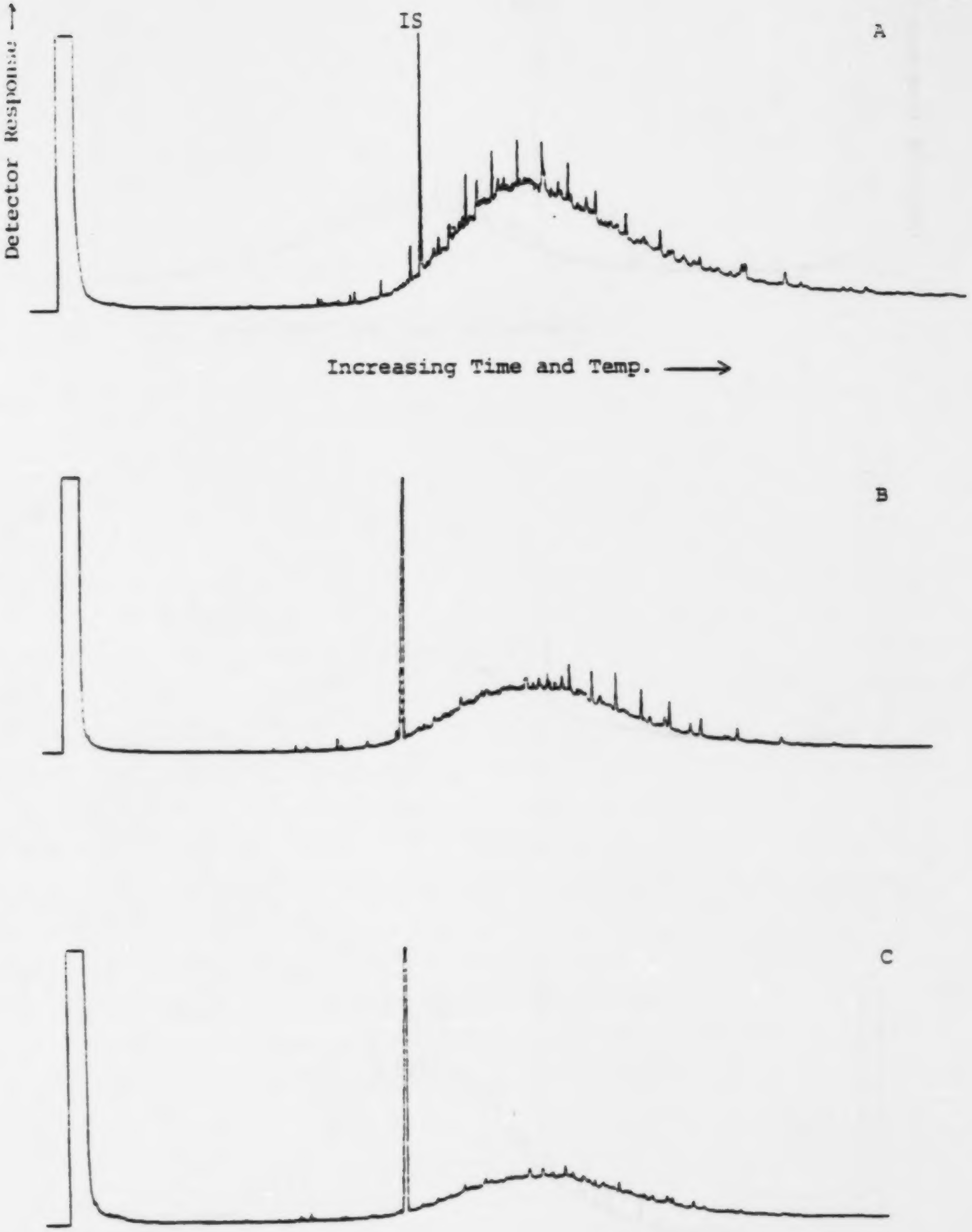


Figure 45. GC-FID analysis of Stormwater runoff. A, aliphatic (f_1) fraction of July 1982 composite sample; B, aliphatic (f_1) fraction of May 1983 - 1st flush; C, aliphatic (f_1) fraction of May 1983 1-hour composite. IS= Internal Standard

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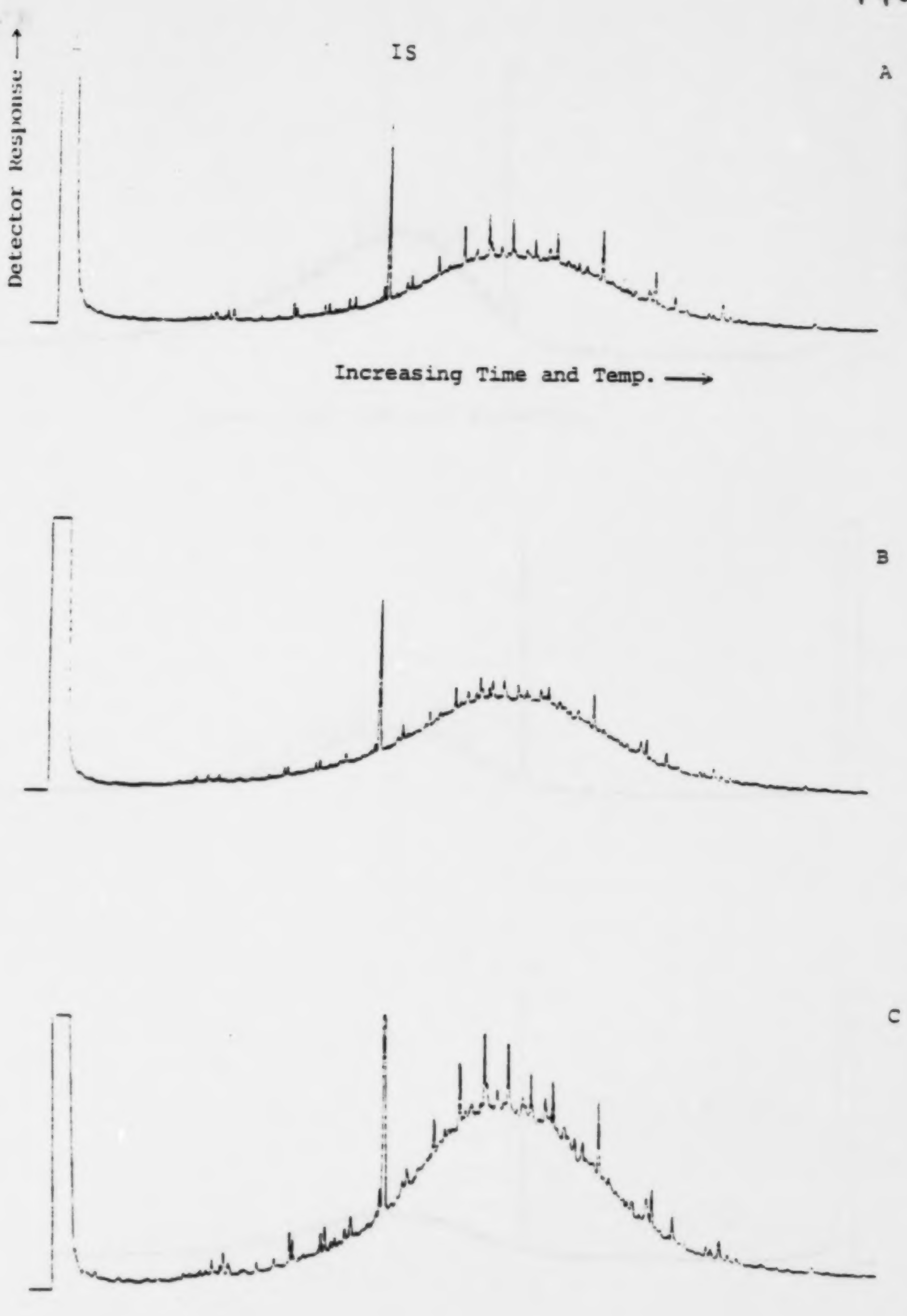

Figure 46. GC-FID analysis of Hillsborough River sediment. A, Sligh Ave.; B, I-275; C, Buffalo Ave.

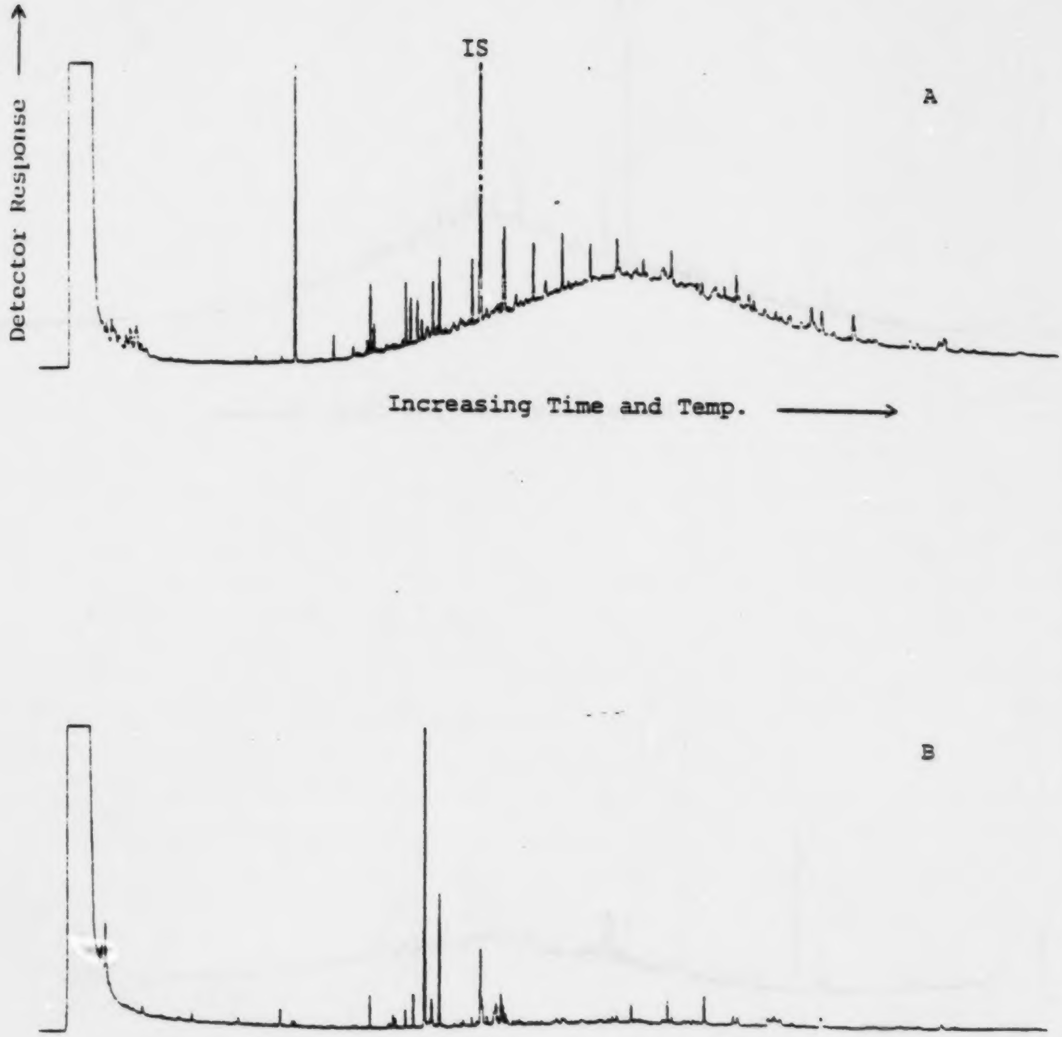

Figure 47a. GC-FID analysis of sediment sample 0-1 (Hillsborough Bay). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

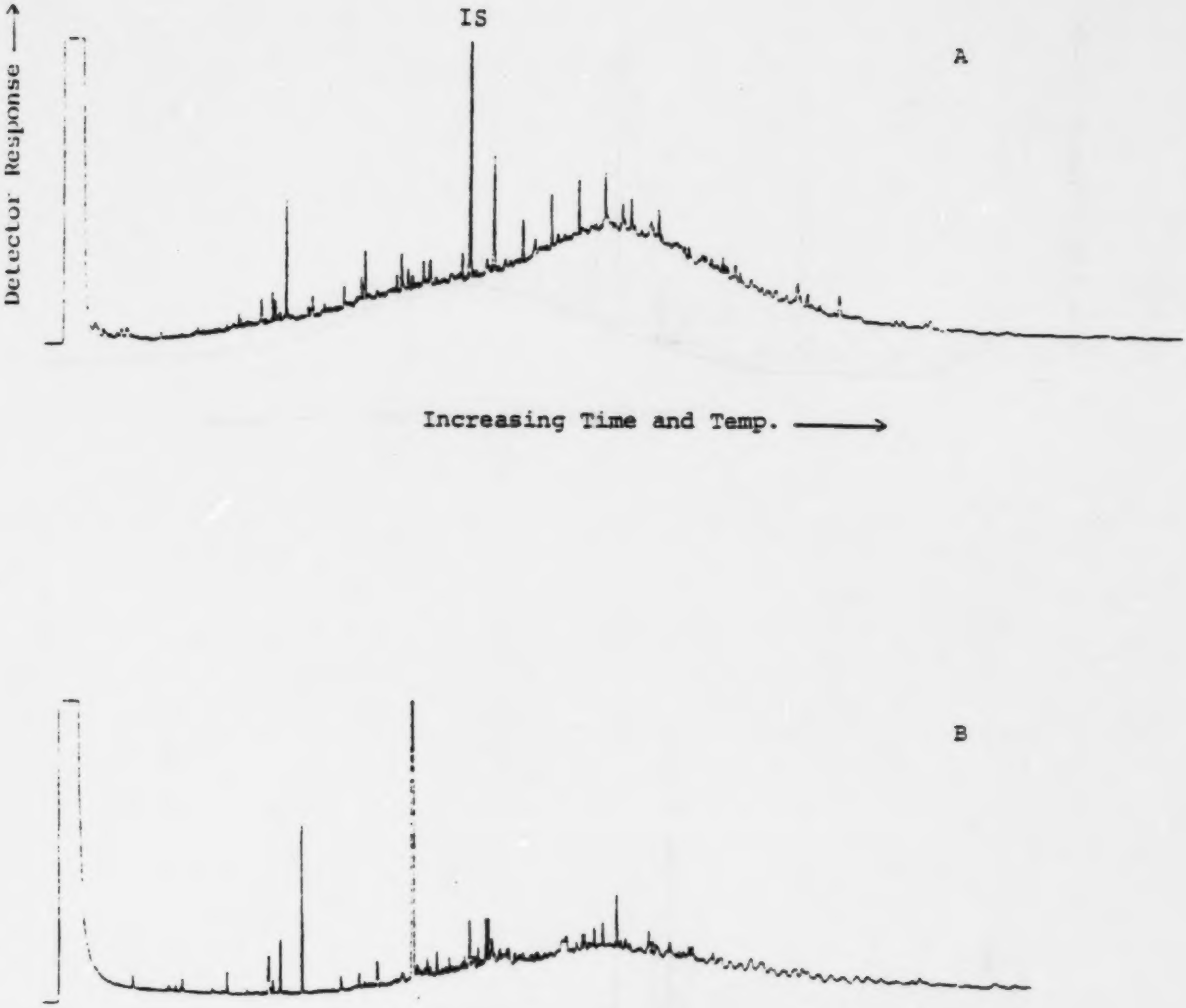

Figure 47b. GC-FID analysis of sediment sample 0-3 (Hillsborough Bay). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

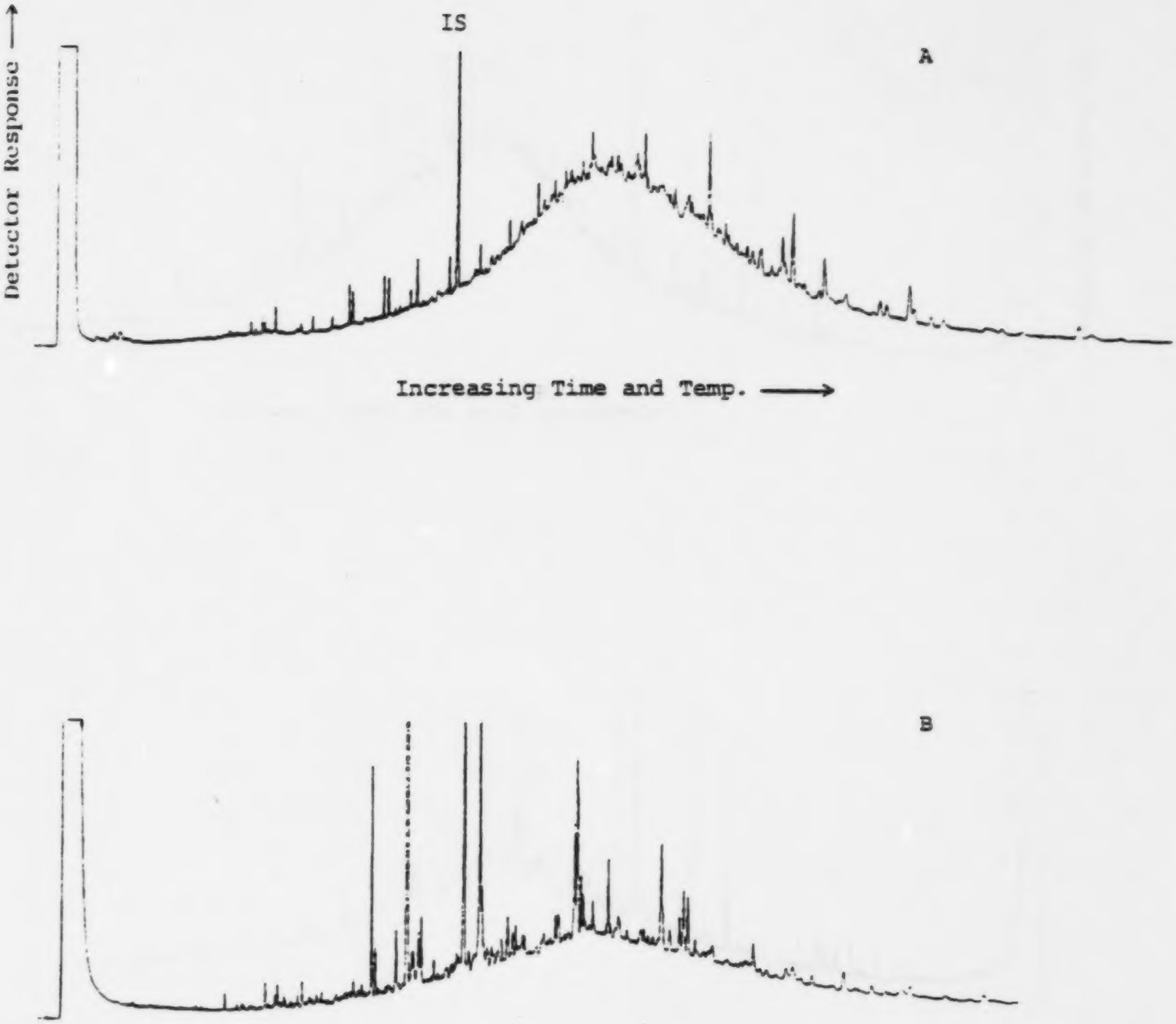

Figure 47c. GC-FID analysis of sediment sample 0-4 (River mouth).
A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

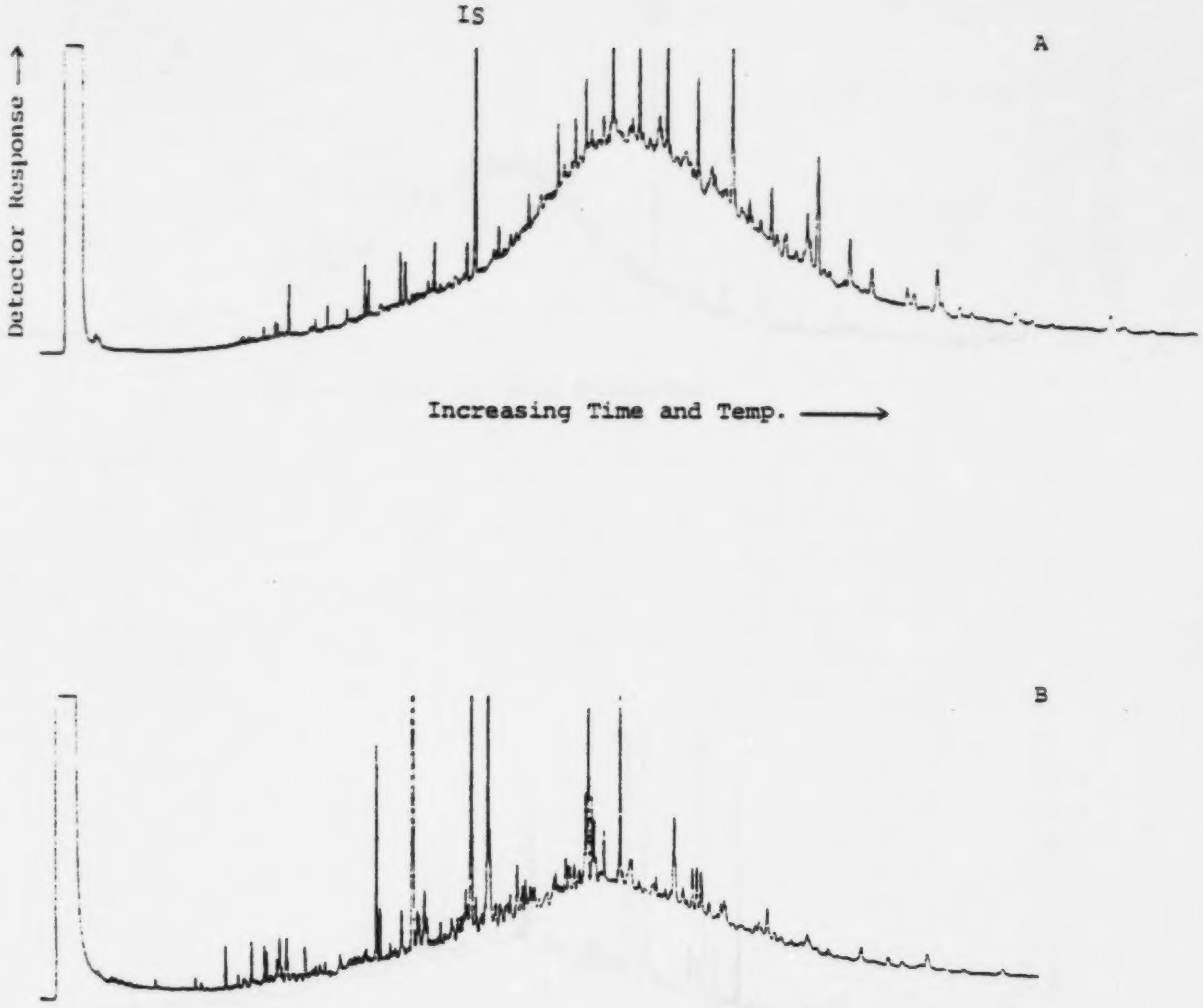

Figure 47d. GC-FID analysis of sediment sample 1-2 (I-275 station). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

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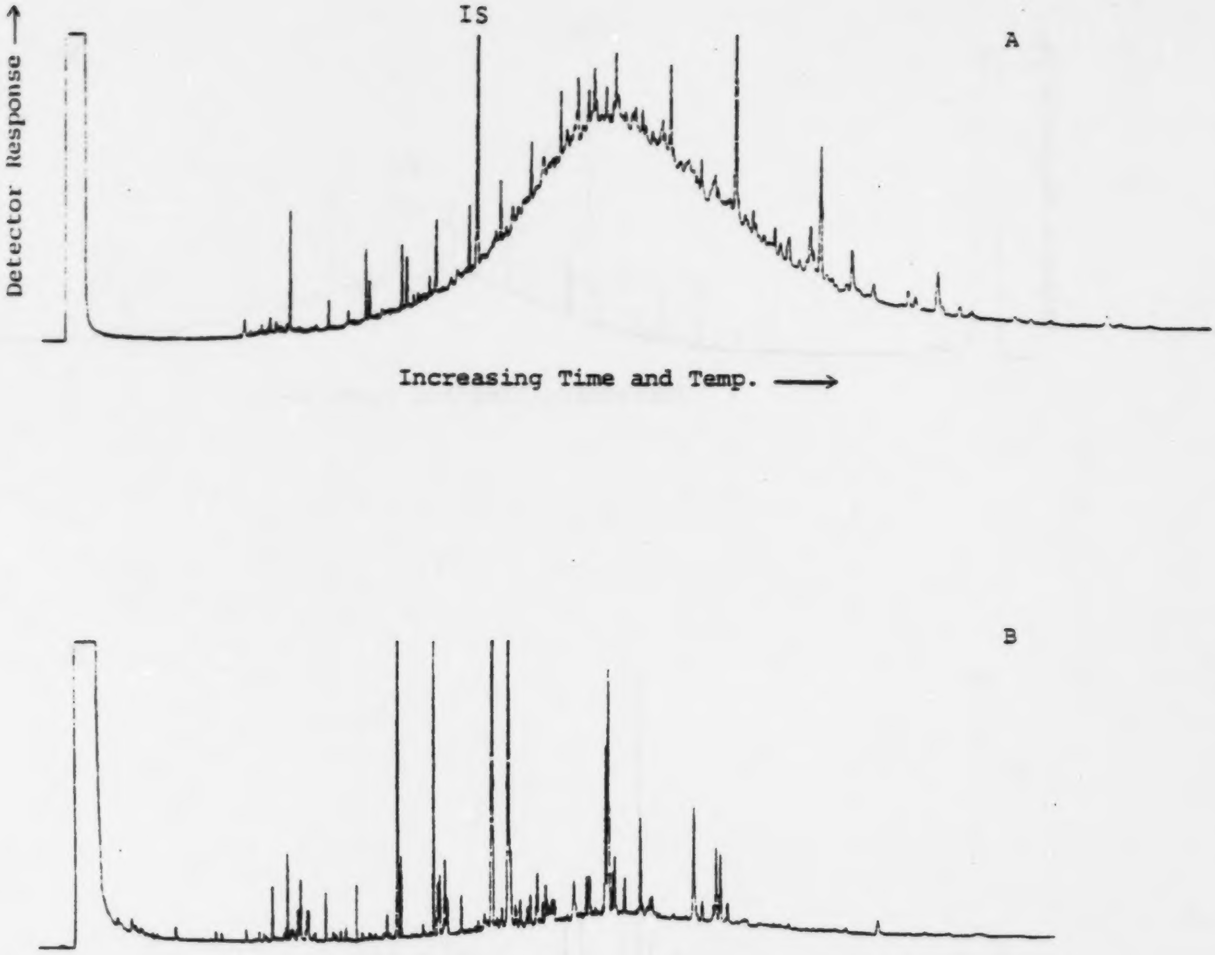

Figure 47e. GC-FID analysis of sediment sample 2-2 (Hillsborough Avenue). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

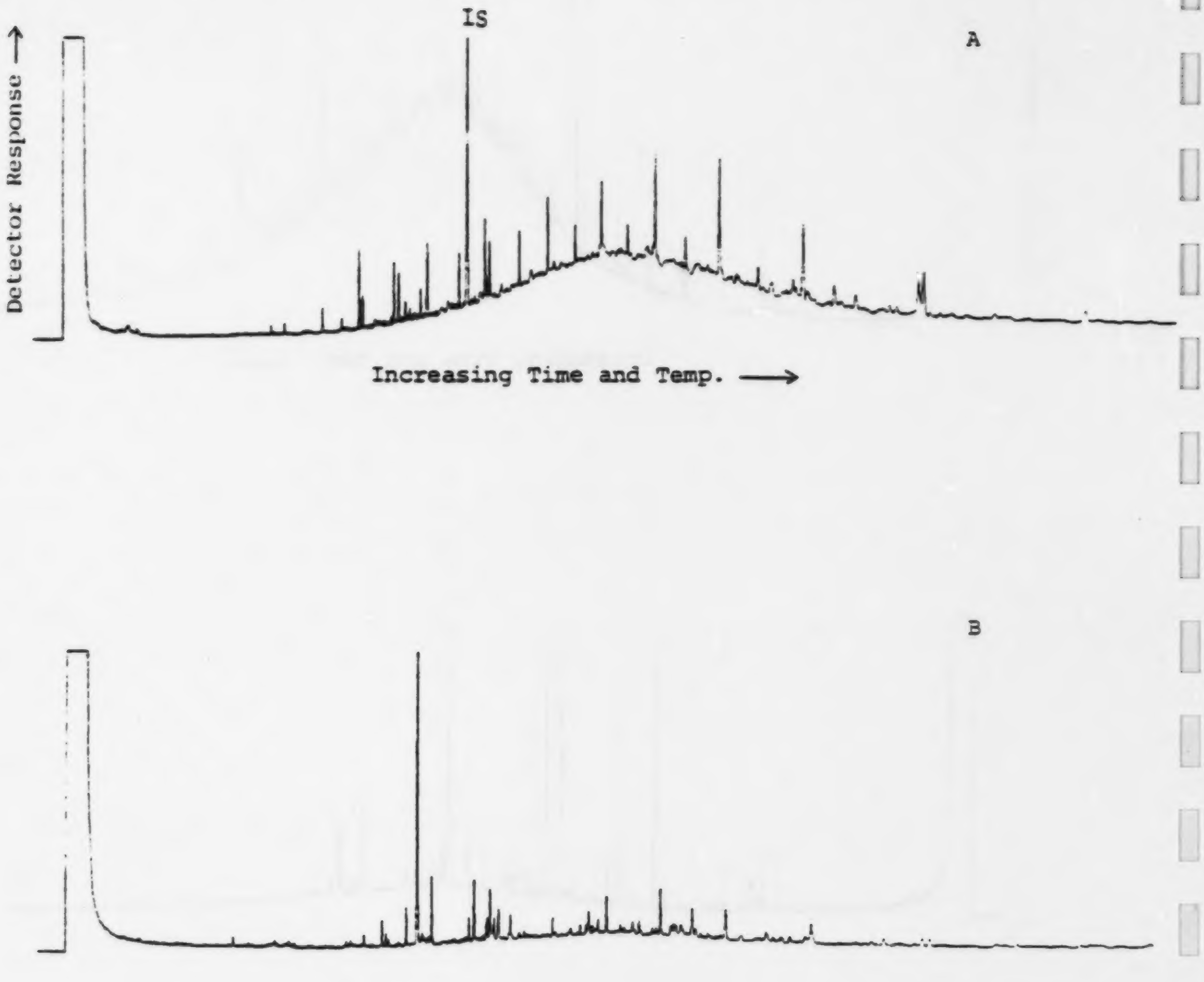

Figure 47f. GC-FID analysis of sediment sample 4-2 (Hillsborough Reservoir). A, aliphatic (f_1) fraction; B, aromatic (f_2) fraction.

Table 26. Hillsborough River Sediment Hydrocarbon Characterization.

SAMPLE	TOTAL (μg/g) f_1	TOTAL (μg/g) f_2	THC[1] $f_1 + f_2$	$\bar{x}$	RATIOS[2] Resol/ Unres.	RATIOS[2] Prist/ Phyt.	RATIOS[2] C_{17}/ Prist.	RATIOS[2] C_{18}/ Phyt.	KEY HYDROCARBONS (ng/g)[3] 1500	KEY HYDROCARBONS (ng/g)[3] 1700	KEY HYDROCARBONS (ng/g)[3] 2100	KEY HYDROCARBONS (ng/g)[3] 2900	N-ALKANES Homol. Ser.	N-ALKANES CPI
0-1A[4]	64.24	10.50	74.74	76.62	0.09	0.34	2.03	1.37	--	63.32	414.21	110.80	C_{17-32}	1.36
0-1B	59.70	18.81	78.51		0.10	0.66	2.05	1.37	--	138.30	330.26	100.00	C_{17-32}	1.63
0-3A	187.52	18.85	206.37	228.70	0.06	0.98	0.47	0.50	465.84	112.85	669.71	118.45	C_{14-31}	2.06
0-3B	228.74	22.29	251.03		0.07	1.14	0.84	1.13	716.50	374.44	503.92	150.52	C_{14-31}	1.73
0-4A	309.62	55.78	365.40	379.54	0.10	1.01	0.98	1.11	179.08	243.36	197.84	1527.72	C_{15-32}	1.52
0-4B	331.48	62.20	393.68		0.06	0.75	1.12	1.07	143.24	230.84	224.64	1332.08	C_{15-32}	2.10
1-1A	246.13	44.47	290.60	283.96	0.07	0.95	1.53	1.48	354.71	285.41	162.77	885.66	C_{14-29}	1.81
1-1B	220.84	56.49	277.33		0.06	0.94	1.28	0.84	383.97	146.63	141.10	774.77	C_{14-29}	2.59
1-2A	387.28	90.73	478.01	484.94	0.08	0.84	1.24	1.32	312.24	278.42	197.07	2369.03	C_{15-32}	1.54
1-2B	405.48	86.38	491.86		0.06	0.84	1.30	1.34	265.60	307.69	279.94	1551.76	C_{15-32}	1.98
1-3A	135.49	20.18	155.67	151.69	0.07	0.77	1.62	1.21	266.54	128.55	127.26	442.21	C_{15-32}	2.00
1-3B	118.78	28.93	147.71		0.07	0.92	1.57	1.06	249.70	97.73	120.80	473.96	C_{15-32}	1.50
2-1A	196.72	63.31	260.03	254.84	0.06	0.80	1.57	1.24	99.71	168.20	153.51	714.46	C_{15-32}	2.00
2-1B	188.75	60.90	249.65		0.07	0.74	1.70	1.37	94.92	226.41	211.20	802.50	C_{15-32}	1.96
2-2A	200.38	89.78	290.16	296.89	0.08	0.69	1.74	1.29	365.96	216.54	225.16	1651.15	C_{14-31}	3.19
2-2B	220.65	82.97	303.62		0.07	0.78	1.71	1.00	483.17	159.47	170.47	1498.02	C_{13-30}	2.31
3-1A	150.18	30.46	180.64	183.88	0.05	0.74	1.40	1.36	96.97	84.91	135.60	455.43	C_{14-31}	1.45
3-1B	149.60	37.53	187.13		0.06	0.65	1.40	1.12	78.50	71.81	180.00	211.81	C_{13-30}	1.31

[1] Total Hydrocarbon Concentration

[2,3] See Table 24.

[4] A and B are duplicate samples

Table 26. Continued. Hillsborough River Sediments.

SAMPLE	TOTAL (µg/g)		THC[1]		RATIOS[2]				KEY HYDROCARBONS (ng/g)[3]				N-ALKANES	
	f_1	f_2	$f_1 + f_2$	$\bar{x}$	Resol/ Unres.	Prist/ Phyt.	C_{17}/ Prist.	C_{18}/ Phyt.	1500	1700	2100	2900	Homol. Ser.	CPI
3-2A	145.16	30.05	175.21	177.65	0.08	1.02	1.21	1.14	124.92	198.90	155.36	929.10	C_{15-32}	2.34
3-2B	136.86	43.23	180.09		0.07	0.79	1.59	0.95	93.96	135.37	156.14	712.06	C_{15-32}	1.28
4-1A	172.92	44.66	217.58	224.12	0.07	0.94	1.14	0.95	71.29	280.48	290.37	1866.60	C_{15-32}	2.71
4-1B	192.53	38.14	230.67		0.08	0.92	0.97	0.55	44.40	211.09	176.61	1425.27	C_{15-32}	2.32
4-2A	161.63	21.96	183.59	170.70	0.10	0.65	2.00	0.91	39.88	227.15	321.23	1173.32	C_{15-32}	3.10
4-2B	128.28	29.52	157.60		0.12	0.64	2.14	1.15	44.40	351.27	278.02	1185.77	C_{15-32}	2.89

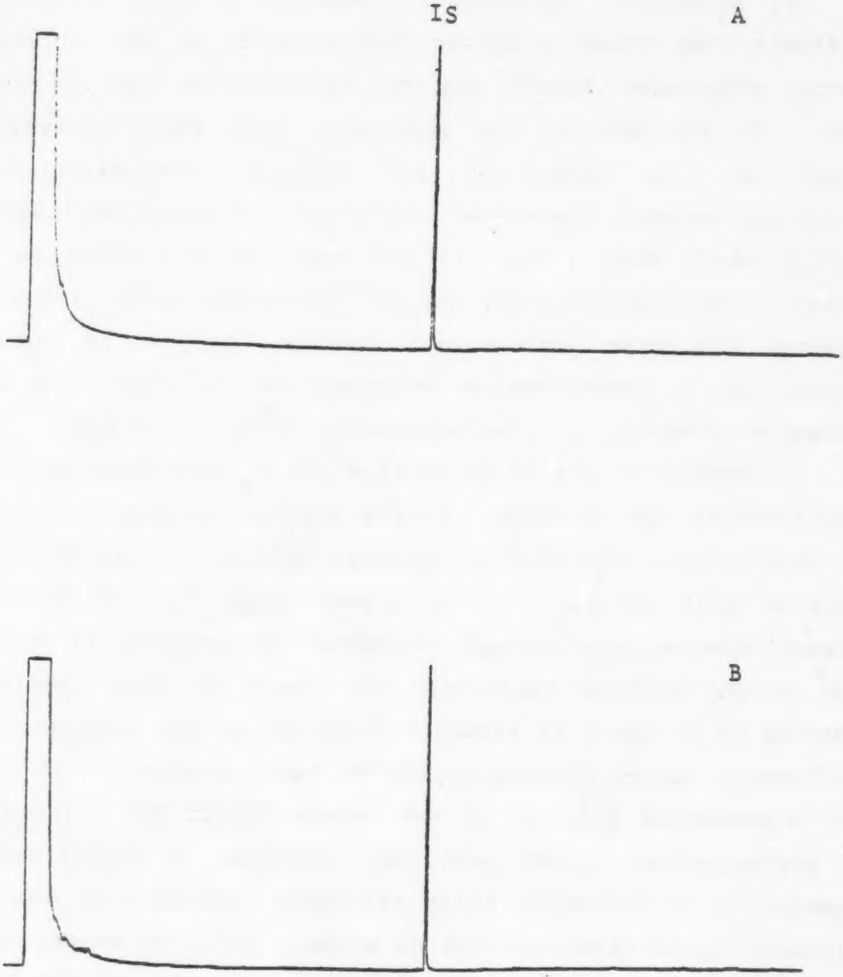

Figure 48. GC-FID analysis of f_1 fraction: A, Procedural blank; B, Station 2-1 (bottom) suspended particulate sample.

IX. CONCLUSIONS AND RECOMMENDATIONS

The scientific information presented in this report represents a significant step toward a better understanding of the pollution potential of urban stormwater runoff and the dynamics of the Hillsborough River system. To the best of our knowledge, this study represents a unique approach to the biological and chemical characterization of the relationship between stormwater runoff and pollution problems in an urban receiving water body. Our ultimate goal in this research has been to integrate a multidisciplinary project including field biological studies, laboratory biological studies and chemical analyses of runoff and river sediments into a comprehensive assessment of the short term and long term degradative potential of urban stormwater runoff in Tampa.

In summing up the major conclusions of this research, the following generalizations can be made: 1) the benthic animals in the Hillsborough River are largely affected by seasonal changes in salinity and flow rate associated with rainfall; 2) a higher proportion of benthic pollution indicator species are present downriver as compared to upriver; 3) wet season runoff contains relatively low levels of toxic chemicals and does not appear to be toxic to estuarine animals; 4) dry season runoff contains significantly higher concentrations of toxic chemicals and can be acutely toxic to estuarine animals; 5) wet season runoff has a stimulatory effect upon phytoplankton growth and may represent a significant source of nutrients; 6) Hillsborough River sediments contain high concentrations of potentially toxic chemicals can be acutely toxic to estuarine animals; 7) major pollutants such as petroleum hydrocarbons in river sediments can be traced to urban runoff as their primary source; 8) based upon hydrocarbon analyses of sediments and suspended particulate matter, Hillsborough Bay has little effect upon pollution loads in the lower river sediments during periods of low river flow; 9) planktonic animals and plants in the river are dominated by river flow rates and salinity changes and are most likely little affected directly by runoff pollutants; and 10) numerous possibilities exist for shoreline improvements along the river to increase stability, decrease the impact of stormwater runoff, and increase aesthetic values.

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A. Benthic Studies

Benthic macroinvertebrates have been used in several studies to document or assess the impact of non-point source pollution. Generally, benthic samples in published studies were collected at regular intervals for one or more years in order to account for seasonal variations. Pratt and Coler (1979) documented a progressive disruption in the macrobenthic community in a river system as it flowed through increasingly urbanized areas. These authors attributed this disruption to increasing urban runoff with the most acute effects seen during low river flow periods. In addition, they suggest that the most significant problems occur in the stream bed where pollutants and particulates may accumulate.

Pitt and Bozeman (1980) studied the chemical and biological characteristics of a river system as it flowed from an unurbanized area through an urbanized section affected by stormwater runoff. They reported that the urbanized section had a lower diveristy of aquatic organisms, increased abundance of pollution indicator species and generally higher levels of toxic chemicals and nutrients.

Benthic invertebrate populations in the Lynnhaven River system (Virginia) were sampled by Dauer et al. (1979) in a study of the effects of non-point sources of pollution. Comparisons of species composition and abundance among three creeks within the river system showed little correlation with quantity of non-point discharge; however, all three creeks contained several pollution indicator species within the benthic community.

Tomlinson et al. (1980) sampled benthic invertebrate populations and measured water and sediment chemistry in the vicinity of two storm drain outfalls in Lake Washington. Their data indicate a general enhancement of oligochaetes and depletion of chironomids in the vicinity of the outfalls. These and other alterations in benthic community composition were attributed to discharge toxicity, substrate alterations and/or smothering by particulates.

In the present research, benthic infaunal communities were found to vary in composition and density of organisms along the Hillsborough River in general accordance with the salinity regime. Highest densities occurred at the more estuarine stations during the dry season. The Hillsborough

River benthos appear to represent a system that seasonally oscillates between an estuarine salinity gradient and an essentially freshwater habitat. The persistence of estuarine species at some stations during the wet season is likely attributable to the capacity of the sediment to buffer the effect of overlying low salinity water for infaunal organisms and to the periodic intrusion of higher salinity water from Hillsborough Bay. It is unlikely that stormwater runoff has much of an acute effect upon benthic communities other than those associated with changing salinities. The long term effect of urban runoff upon benthic communities, however, may be substantial, especially at downstream stations, and is manifested in the accumulation of stormwater borne particulate matter with its associated pollutants. The accumulation of this particulate matter in river sediments may affect benthic organisms through direct toxicity (discussed below under Animal Bioassays) or through reduced dissolved oxygen levels. Many of the benthic species identified at river stations are also present in Hillsborough Bay where annual defaunation due to low dissolved oxygen levels have been well documented (Santos and Simon, 1980a; Santos and Simon, 1980b; Santos and Bloom, 1980). Reducing the rate of input of runoff particulate matter and/or removal of accumulated sediment in the lower river would lead to improved water quality and likely a reduction in the presence of pollution indicator species. Periodic sampling of benthic invertebrates, especially at downstream stations during the dry season, could provide a good indication of the success of mitigative procedures.

B. Animal Bioassays

Urban stormwater runoff is a very heterogeneous effluent. Both quantity and quality of runoff can be highly variable. Even the same drainage basin may produce very different effluents, depending upon the intensity of the rain event and the number of antecedent dry days. To compound matters further, the quality of runoff from a single outfall often varies temporally during the course of a storm event. For these reasons, a single drainage basin was selected to provide stormwater for toxicity testing. This drainage basin, the Artic Street basin, is described in the Introduction section of this report and was selected because of its balanced land use characteristics. The stormwater runoff from the Artic

Street basin was presumed to represent more or less "average" runoff for the greater Tampa Bay region.

Chemical analyses of stormwater runoff used in bioassay experiments (Tables 9 and 27) revealed heavy metal and hydrocarbon concentrations that could be potentially toxic to estuarine animals. The results of bioassay experiments using runoff samples, however, revealed an unexpectedly low toxicity relative to the concentration of pollutants revealed by chemical analysis. This lower than expected toxicity pattern was also evident in tests with whole sediment and suspended particulate matter. The reasons for these discrepancies are likely related to the fact that most potentially toxic chemicals in stormwater runoff are bound to particulate matter and that contact of runoff with saltwater causes precipitation of pollutants due to reduced solubilities.

Li (1975) reported that many pesticides, especially the least water soluble ones, adhered to particulate matter in stormwater runoff and were transported to receiving waters. Hunter et al. (1979) found that on the average 86% of the petroleum hydrocarbons in urban runoff were associated with particulate matter. Heavy metals often form relatively insoluble complexes, particularly in seawater, and tend to become adsorbed onto suspended particles (Renfro, 1973; Etcheber and Jouanneau, 1980).

Giovannelli and Murdoch (1983) reported that in most cases dissolved concentrations of lead, zinc and copper from the Artic Street drainage basin accounted for 50% or less of the total concentrations of these metals. Major reduction in solubility of these metals are known to occur at salinities above 15 ppt (Callahan et al., 1979) and thus the soluble fraction reported above could be significantly reduced upon mixing with estuarine water. Lum et al. (1982) tested a method of sequential chemical extraction of urban particulate matter for determination of soluble or exchangable forms of heavy metals relative to total heavy metal content. They concluded that a high proportion of heavy metals such as cadmium, copper, lead, and zinc, among other elements, were present in urban particulate matter in readily bioavailable form. These determinations were made under specific laboratory conditions and may not be representative of the bioavailability of these pollutants in seawater solutions.

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Considerable research has been conducted with contaminated sediments as part of the U.S. Army Corps of Engineers Dredged Material Research Program. Some of these studies conclude that most pollutants associated with harbor sediments (which probably resulted from runoff particulates) are not present in readily bioavailable form and thus do not pose a problem in ocean water (Neff et al., 1978). Olsen (1980) reviewed the Corps' dredged material literature and concluded that site specific physical, chemical and biological factors are all important in determining the bioavailability of sediment associated pollutants.

In an estuarine system like the Hillsborough River, several factors interact simultaneously to determine the form and effect of sediment associated pollutants. These factors include salinity, temperature, dissolved oxygen levels, pH and microbial activity. As these factors change and interact, sediment associated pollutants may be released into the water in toxic forms or alternatively precipitated as bound complexes.

Based upon the results of this study, urban stormwater runoff does not appear to pose a significant acute toxicological problem to animal life in the lower Hillsborough River. Rapid dilution of runoff and mixing with estuarine water would both reduce the toxicity of runoff under field conditions. The only conditions under which urban runoff might be acutely toxic within the river system would be during a dry season rainfall event where runoff entered the river under low flow conditions and low salinities. Calculation of LC_{50} values for the runoff samples tested would serve no useful regulatory purpose since so many factors may influence toxicity of runoff.

Stormwater runoff does pose a serious pollution threat through accumulation of particulate matter and associated pollutants in river sediments. The acute toxicity of river sediments to some bioassay organisms indicates that not all sediment associated pollutants are bound in nontoxic form. It should be noted that the sediment bioassays reported above were carried out under the least toxic conditions of high salinity and high pH. The potential clearly exists for acute and chronic toxic effects to occur in river fauna due to accumulation of stormwater borne pollutants. The presence of carcinogenic agents such as cadmium and certain aromatic hydrocarbons suggests that chronic effects may be expressed in forms other than were analyzed in the present research (i.e., carcinogenesis, teratogenesis, turmorogenesis).

The suspended particulate phase (SPP) bioassays conducted with Hillsborough River sediments were intended to assess the acute toxic potential that might occur after disturbance or resuspension of bottom sediments. These tests were carried out under various combinations of pH and salinity in order to determine the effect of these parameters upon toxicant release from the sediments. The SPP displayed the highest toxicity under conditions of low salinity as was the case with whole stormwater. These results suggest that resuspended sediments from the Hillsborough River could be toxic, especially to invertebrates, if resuspension occurs under low salinity conditions.

Long term improvements in river water quality will only come if procedures are implemented to remove and/or control input of stormwater associated particulates and pollutants. Although the sediment and suspended particulate phase bioassays conducted during this project followed general guidelines established by EPA/COE (1977), they were not intended to assess the suitability of Hillsborough River sediment for ocean disposal following dredging. If appropriate, this assessment should be carried out separately; however, based upon the results of this research, Hillsborough River sediments would not likely pass the bioassay criteria for ocean disposal.

C. Algal Assays

The effects of stormwater runoff upon natural and cultured phytoplankton have been relatively well documented and successfully used to predict potential problems, especially for enclosed water bodies. Stormwater runoff has been shown to be a significant source of nutrients for phytoplankton, often leading to eutrophic conditions and reduced water quality in receiving waters. Yousef et al. (1980) found that high concentrations of stormwater runoff entering Lake Eola in Orlando, Florida, inhibited phytoplankton growth, while diluted stormwater stimulated growth. Gaggiani and Lamonds (1978) reported similar enrichment of lake water due to runoff, leading to phytoplankton blooms in other Florida lakes. There appears to be a balance between phytoplankton growth stimulation and inhibition in runoff that can be attributed to nutrients and toxic chemicals, respectively.

The Hillsborough River system is not an enclosed water body and thus would not be expected to show as severe an effect from nutrient addition as would a lake. Most of the nutrients entering the river via runoff are probably transported to Hillsborough Bay rather rapidly, especially during the wet season.

Algal assays with Artic Street runoff suggest that wet season stormwater stimulated phytoplankton growth even at high concentrations. For management purposes, it would be instructive to know what effect filtration of stormwater would have on available nutrients and how nutrients and toxic chemicals affect phytoplankton growth in dry season runoff.

D. Plankton Studies

Analysis of zooplankton and phytoplankton populations in the Hillsborough River indicates that river flow rates have a profound effect upon these communities. Generally, plankton communities display higher diversity and higher abundance of individuals under marine or estuarine conditions than under freshwater conditions. This is consistent with the observation that plankton densities were higher at all stations during the dry season than during the wet season. Marine organisms were predominant at all but the most upstream station during the dry season and decreased in relative abundance during the wet season. The most downstream station maintained a dominance of marine plankton even during the wet season, indicating that Hillsborough Bay has a strong effect upon the composition of the plankton community throughout the year.

E. Lower Hillsborough River Shoreline Inventory

The Hillsborough River, from the dam to the bay, has been moderately to severely altered by urbanization. Calculations reveal that 54% of the shorelines have been hardened. Of the hardened portions, about 47% are composed of bulkhead, while about 8% are riprap. Approximately 13% of the river's shores are filled but unhardened, and 34% are more or less native (a total of 102% for these figures is due to their nonexclusive nature).

Native vegetation along the river shows a general transition from salt-tolerant species downriver to salt-intolerant forms upriver, although this pattern has been modified due to historical and natural causes.

Four main recommendations can be made based upon the information collected during this survey. These include:

1) The City of Tampa should concentrate on the river section between Sligh Avenue and North Boulevard as the preferred area for immediate shoreline improvements;

2) A three phase plan for shoreline improvements should be developed for the target segment including: a) creation or restoration of vegetated shorelines on public lands; b) removal of exotic plant species from natural and filled shorelines; and c) enhancement of riprap shorelines with native vegetation;

3) The City of Tampa should involve citizens and shoreline owners in waterfront improvement through development of homeowner's guides and incentive programs; and

4) The City of Tampa should seek a formal role in the permit review and approval process affecting dredging, filling or shoreline construction in the Hillsborough River, beyond that currently exercised through planning, review or code enforcement programs.

F. Hydrocarbon Studies

The hydrocarbon content of sediments collected throughout the entire study area (lower Hillsborough River, upper Hillsborough Bay and Hillsborough Reservoir) and from stormwater runoff collected from the Artic Street watershed was dominated by petroleum indicative of crankcase oil-like material. Characteristic biogenic (natural) hydrocarbons were also present in sediments but these were less abundant than the petroleum component. Sediment petroleum content increased from the reservoir downstream to a maximum near the I-275 bridge. Concentrations then decreased toward the river mouth and into Hillsborough Bay.

The hydrocarbon content of particulate matter in the stormwater runoff was about ten times that found in river sediments, indicating that stormwater was a major source of petroleum contamination in river sediment.

Surface and bottom water samples were collected simultaneously with sediment samples and were analyzed for hydrocarbons associated with suspended particulate matter. These analyses revealed no petroleum contamination in surface (freshwater) or bottom (saltwater) samples.

These results show that Hillsborough River sediments are contaminated with petroleum of crankcase oil-like material. The primary source of this material is from stormwater runoff. No upriver transport of resuspended sediment was observed from the bay or river mouth during a rising tide with low river flow conditions.

This last conclusion appears to be in conflict with the contention that upstream tidal transport in the lower river is contributing to sediment accumulation (Metcalf and Eddy, 1983b, pg. 4-11, 6-4). It would seem more likely, based upon the present evidence, that saltwater intrusion into the river may obstruct particulate transport downriver and thus result in accumulation of sediments. This proposed obstruction could occur through physical forces such as higher density saltwater opposing downstream flow of freshwater or through chemical forces such as flocculation of minerals and generally lowered solubilities of metals in saltwater. It may be that during periods of high suspended particulate loads in the river, as occur following heavy runoff, tidal forces may carry some material upstream and contribute to its deposition. Upstream transport, however, does not appear to occur during low river flow conditions. The relationships between river flow and tidal flow need to be addressed under high river flow conditions in order to understand the net effect of freshwater and saltwater interactions. Subsequent studies on sediment chemistry should concentrate on the river section near the I-275 bridge, since this area contained the highest concentrations of petroleum hydrocarbons and also produced the highest sediment oxygen demand (SOD) reported in the river (Metcalf and Eddy, 1983b). This portion of the river probably represents a major interaction point between freshwater from upriver and saltwater from the bay. Chemical analyses of sediment core samples from Sligh Avenue to Platt Street would be useful in determining the volume of contaminated sediments to be dealt with.

G. General Conclusions

Stormwater runoff entering the lower Hillsborough River does not pose an acute toxicological problem to most endemic biota. Rapid dilution rates of stormwater and chemical complexion of pollutants into insoluble forms upon contact with saltwater reduce the direct toxicity of runoff. Based upon chemical composition alone, the acute toxic potential of stormwater runoff would be over estimated, since much of the potentially toxic material is bound in non-bioavailable form. Most state and federal water quality standards are based upon chemical composition rather than actual toxicity and thus urban stormwater runoff may contribute significantly to water quality violations.

Table 27 summarizes the state and federal water quality criteria and compares these values to measured levels in urban runoff and receiving waters. The fact that different water quality criteria have been established for freshwater as opposed to saltwater makes interpretation difficult with respect to a variable system like the Hillsborough River. In addition, no criteria exist for petroleum hydrocarbons, yet these pollutants are present in high concentrations in runoff and sediments and may represent a significant threat to water quality.

Dilution rates of stormwater runoff appear to be sufficient in the river to reduce heavy metal concentrations to below water quality criteria (with the exception of copper and zinc at certain times).

The chemical data presented in Table 27 for "first flush" runoff indicates that pollutant levels may be over seven times higher in this water than in "average" runoff from the same storm event. This suggests that control measures for limiting input of runoff pollutants should include mechanisms to divert or retain this first flush material and prevent it from directly entering the river.

Pollutant loads in average river sediments (Table 27) are alarmingly high and will need to be dealt with before significant improvements in water quality can be expected. Recommended actions to alleviate this problem includes: 1) removal of existing contaminated sediments from the river; and 2) implementation of the stormwater management plan (Metcalf and Eddy, 1983a) and the recommended improvements in the Hillsborough River shoreline (this report) to provide a long-term system for limiting pollutant input into the river.

Table 27. Comparison of water quality criteria with values measured in Hillsborough River sediments, water and runoff.

SOURCE	Copper ug/l	Cadmium ug/l	Lead ug/l	Mercury ug/l	Zinc ug/l	Petroleum ug/g Hydrocarbons
EPA[1]	22 (23)	3.0 (59)	170 (NA)	4.1 (3.7)	320 (170)	--
Florida[2]	30 (15)	0.8 (5)	30	0.2 (0.1)	30 (NA)	--
Average Wet Season Runoff	26	4	207	0.75	166	608
Dry Season Runoff	38	4	500	--	530	618
Dry Season First Flush Runoff	--	30	1600	--	970	2037
Average River Sediments	--	1000	107000 ug/kg (wet wt.)	--	69000 ug/kg (wet wt.)	267
Suspended Particulate Matter[3]	--	10	2800	--	2065	0
River Water[4] April 1982	3-6	--	4-26	--	20-90	--
River Water[4] November 1982	13-57	--	8-22	--	3.6-22	--

[1] EPA Ambient Water Quality Criteria for Protection of Aquatic Life, November, 1980, 45FR (231) and 46FR (40199). Values represent acute freshwater level followed by acute saltwater level; NA = Not available.

[2] State of Florida Water Quality Standards for Class III Waters (Chapter 17-3). Values represent freshwater standard followed by saltwater standard; Fla. Dept. Environ. Reg. Supp. No. 123.

[3] Suspended particulate matter values for heavy metals obtained from laboratory resuspension of sediments (see Section III, Animal Bioassays); hydrocarbon analyses represent field collected particulate matter.

[4] Data from Metcalf and Eddy (1983a).

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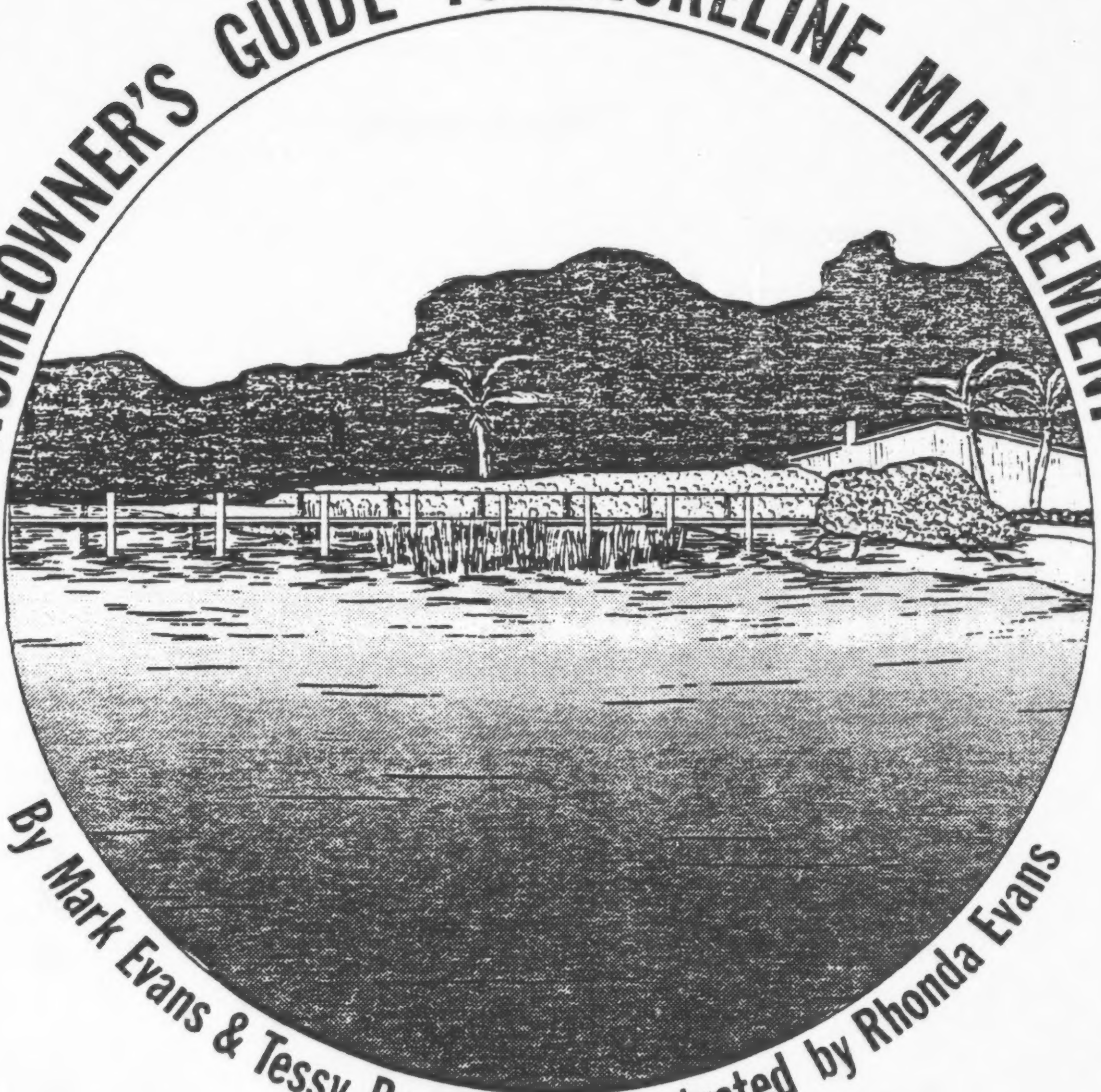
APPENDIX I: Excerpts
from

HOMEOWNER'S GUIDE TO SHORELINE MANAGEMENT



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INTRODUCTION

The beaches, bays, bayous, and tidal creeks of Sarasota County are some of the most important resources and attractions of this area. As more people come to the Sarasota area, there is an increased demand for shorefront homesites, marinas, and parks. This demand has resulted in considerable change in the character and function of the shorelines. From 1948, there has been a 20% decrease in mangroves, an 8.3% decrease in salt marsh vegetation, and a 668% increase in seawalls and revetments. Additionally, there has been an increase in shorelines susceptible to erosion due to the spread of Australian pine. Together with the alteration of our shorelines, there must be an effort to maintain and preserve the quality of those areas. There are no easy solutions to the problems of shoreline development, but the following guide is an approach to responsible management.

This booklet is designed to provide the residents of Sarasota County with specific information and techniques necessary for the proper development and maintenance of their shorefront properties along the salt water shorelines in Sarasota County. This booklet will begin with a general description of the ecological processes of the shore. Next, each type of shoreline in Sarasota County will be described with development and maintenance alternatives, including a few selected references that should be of interest to anyone requiring additional information. Finally, information on the use, availability, and maintenance of shoreline plants will be given, along with related local, state, and federal regulations.

TABLE II: ESTIMATED COSTS OF SHORELINE STABILIZATION[1]

	Vegetation		Concrete Seawall		Stone Revetment	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
PERMITS[2]	not req.	not req.	$450	$600	$450	$600
CONSTRUCTION	$0.00	$600[4]	$4500[5]	$10000[5]	$4000[5]	$13000[5]
MAINTENANCE	$0.00	$60/yr.[6]	$225/yr.[7]	$500/yr.[7]	----[8]	----[8]
TOTAL INSTALLATION COST (EXCLUDING MAINTENANCE)	$0.00	$600	$4950	$10600	$4450	$13600

1. Single family lot; 100 feet of waterfront
2. Engineering estimates from Steven Houghton, P.E.
3. Utilizing existing plants or available materials and 'do-it-yourself'.
4. Quoted from Robert M. Snyder, Snyder Oceanographic Services. Conference on Restoration of Coastal Vegetation in Florida., 1978.
5. Based on "Seawall and Revetment Effectiveness, Cost and Construction", C.A. Collier, 1975.
6. Figured as one hour/month for trimming, pruning, etc. at $5.00/hour.
7. Based on 20 year life expectancy and eventual replacement.
8. There are no reliable estimates for revetment maintenance, however, proper maintenance would include: filling voids, restoration of the facing and slope, possibly involving eventual replacement.

APPENDIX I

Shoreline Plants for Conservation and Beautification

This appendix presents a list of useful shoreline plants which are of primary importance to Sarasota County residents. All of the species listed are native to this part of Florida. Native vegetation is recommended for several reasons:

1) Native shore plants play a major role in eco-system dynamics. These plant and animal communities have evolved and interacted for thousands of years and are best suited to the local environment. They are valuable to man for food production, recreation, aesthetic pleasure, and storm protection.

2) Native plants have certain characteristics that insure their survival in the harsh shoreline environment. Salt water inundation, exposure to wind and waves, alkaline soils, periodic cold spells, and the extreme pattern of wet and dry seasons are some of the rigors of the shoreline habitat.

3) Because they are adapted to the harsh environment of the shore, native plants require almost no maintenance, such as fertilizers, insecticides, or watering, after they are established, although some planting guidelines recommend initial fertilization.

At this point, it is important to note the problems associated with exotic and imported plants. Because these plants are not native to this area, most of them are not adapted to the local environment, and require special attention, such as watering during the dry season. The exotics that can grow without special attention often grow unrestrained and eliminate native vegetation through competition, causing problems because they are not effective at stablizing shorelines.

An example of a particularly troublesome exotic plant is the Australian pine (Casuarina sp.). These trees were introduced to southern Florida in the early part of this century and have since spread rapidly. They are highly salt tolerant and often colonize beaches and other shores. They have wide, shallow root systems that are easily undercut by waves, making them susceptible to erosion. This shallow root system, coupled with their relatively great height, makes them extremely vulnerable to strong winds; examples of overturned trees are evident on many beaches. For these reasons, Australian pine is unacceptable as a shoreline plant.

However, many shorelines in Sarasota County are already colonized by Australian pine and need to be properly managed. In areas where the trees are not yet very large, they could be topped and trimmed to be maintained as shrubs or hedges, thus preventing them from becoming topheavy. Additionally, Australian pines grow and reproduce very rapidly, requiring constant thinning, removal and maintenance. On some shorelines, it is appropriate to gradually eliminate the Australian pines and replace them with native vegetation. This can be accomplished by cutting down one or two trees at a time and replacing them with the appropriate native plants. When these plants have become established, a few more trees can be replaced, and so on until the pines are eliminated.

PA/lc 11/7/83

APPENDIX II

HILLSBOROUGH RIVER STUDY

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I. Introduction

A. Purpose of the study

(a) problem identification and analysis
(b) establish principles and standards for use
(c) develop an urban river plan
(d) establish an immediate action program for problem resolution.

B. Scope of the study

(a) delineation of the study area (e.g. from the southern most boundary of Hillsborough River State Park to the Platt Street Bridge.
(b) river uses and controls
(c) adjacent land-use controls (e.g. up to 500' on either side of the river).

II. Research Methodology

A. Survey of existing conditions

(a) physical-environmental
(b) legal jurisdiction and authority
(c) river access-usage
(d) adjacent land-uses
(e) special problems.

III. Findings and Conclusions

A. Problems

(a) aesthetics
(b) traffic
(c) safety
(d) access
(e) water quality, supply
(f) nuisances
(g) use compatibility

B. Principles and Standards

(a) citizen participation

C. Plan Alternatives

(a) citizen participation

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IV. Recommended Plan

A. Goals, Objectives

B. Policies, Ordinances (by jurisdiction) "regulatory controls"

C. Action Program (by jurisdiction) "capital improvements).

Activity 1. Establish Policy Committee

Methodology - A general policy committee should be formed consisting of members representing each of the various agencies and jurisdictions which exercise authority over some aspect of River use. The purpose of this committee is to review staff reports and recommendations for its potential impact upon their jurisdictions and to coordinate the policies and actions of each. All participating agencies and jurisdictions should be asked to adopt the final plan.

Activity 2. Establish Citizen Advisory Committee

Methdology - A Citizen Advisory Committee should be formed consisting of one or more persons from the following groups: property owners within 500 feet of the river, members of organized user groups, and occasional users. These persons should be selected at randon from those in attendance at each of the first two citizen participation meetings. The general public will be encouraged to attend all citizen Advisory Committee meetings.

Activity 3. Data Collection

Methodology - Data collection for this study shall be undertaken in six principle categories as shown on the outline. The first, literature review, will consist of identifying, selecting and reading secondary source material pertaining to similar studies of comparable urban rivers as well as any prior studies of the Hillsboroguh River itself. Data collected in this category will be used to further refine our own methodology, to establish principles and standards, and to transfer the application of successful techniques employed elsewhere.

The Physical inventory is a primary data collection activity which consists of field observations. Staff will prepare base maps and develop codes which can be taken into the field to record all the existing physical features of the river. This will entail one or more boat trips up the river. Examples of the observations to be recorded are riverbank conditions, bridges, clearances, structures in and on the water,among others.

The river use survey is another primary data collection activity. Like the physical inventory,forms must be developed for use in recording various field observations. Because river use is seasonal in nature, this activity is scheduled to take place over an eight month period. This will insure capturing the peak use periods. Because the river is so long and manpower is so short, citizen volunteers, students and City Parks Department Personnel will be recruited for assistance. Examples of observations to be recorded are days of the week, time of day, frequency of traffic by type of craft, etc.

The land use survey will consist principally of in-house mapping as much of this data has already been collected in connection with the land use plan. Existing and proposed land use regulations will be overlayed for easy analysis.

The user survey is distinguished from the river use survey by the fact that the former personally interviews the user with respect to the type and frequency of use as well as his attitudes toward the river. The same result could be obtained in a number of alternative ways (such as a mail questionnaire) although with some compromise of accuracy. The user survey is best scheduled during the peak months of May - July because it allows us to "test" user reactions to various proposed river management policies.

Finally, the public policy review will study the rules and regulations of each governmental jurisdiction for their impact upon river use. The data collected here will be used to develop some sense of commonality and coordination among agencies.

Activity 4. Progress Report

Methodology - Staff will prepare a progress report for the Planning Commission giving the status of all study activities undertaken to date. Since the early part of the study will be mostly data collection, no special meetings, discussions or recommendations are contemplated in connection with the report.

Activity 5. Data Analysis - See #6 below.

Activity 6. Progress Report

Methodology - Various data analysis tasks are timed to coincide with the completion of their respective collection activities so as to produce a problem identification report at the earliest possible date. This report will be the focus of discussion and input from citizens' groups, policy people and the Hillsborough County Planning Commission.

Activity 7. Review and Comment

Methodology - Meetings will be held with all interested parties to seek their comments on the second progress report. The meetings will be scheduled subsequent to the distribution of the report to allow for maximum meaningful participation.

Activity 8. Principles and Standards

Methodology - Based upon prior steps, staff will develop principles and standards to be applied in guiding future river use and development. Those principles and standards will constitute the framework within which all subsequent planning will be conducted. Examples of principles and standards might include minimum acceptable water quality, segregation of clearly incompatible uses, and minimum man-made flow alterations. Such principles will be used to define and delineate the number of alternative use, management and design concepts proposed for each problem identified by prior analysis.

Activity 9. Develop Alternative Use and Design Concepts

Methodology - Recognizing that there is probably no single best solution or a solution which will satisfy everyone, several alternatives will be generated for public discussion. Specification of the topics would be premature at this time except to state that there should be a variety of ways to address each of the problems identified.

Activity 10. Develop River Management Concepts

Methodology - This task will, perhaps, be the most problematic for staff as it may involve the administration of such devices as user fees, capital improvements and rule enforcement. Proposed management concepts will be derived from discussions with the key policy people from each of the relevent jurisdictions.

Activity 11. Progress Report (see 12 below)

Activity 12. Review and Comment

Methodology - The third progress report will be the product of Activities #9 and #10. Meetings will be held and input solicited from all interested groups. Consensus-seeking arrangements will have to be employed among members of the policy committee and the HCCCPC in order to arrive at key policy decisions.

Activity 13. Develop River Plan

Methodology - The River Plan will be the final product of this effort and will contain for each jurisdiciton: goals, objectives, implementation strategies and an action program for the near term. To the extent possible, actions will be coordinated among jurisdictions and functionally linked via their budgets to the responsible line departments.

Activity 14 - 20. Document Approval, Reproduction and Distribution

Methodology - (Self explanatory).